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Western Electric Company

ENGINEERING DEPARTMENT

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BULLETIN
A-1

PRINTING TELEGRAPHY

A TECHNICAL DESCRIPTION OF THE WESTERN ELECTRIC PRINTING TELEGRAPH SYSTEMS

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CHARACTERISTICS OF THE IDEAL TELEGRAPH SYSTEM

1. ACCURACY

The ideal telegraph system must be accurate; that is, the delivered messages must correspond exactly to the originating messages.

2. SPEED OF SERVICE

The ideal system must be capable of handling telegraph traffic with a minimum of delay.

3. FLEXIBILITY

The ideal system should possess a maximum of flexibility in order to meet varying traffic and operating requirements. It should be capable of working over different kinds of lines, and should not be permanently tied up with one type of transmission system.

4. LINE ECONOMY

The ideal system should be capable of handling a maximum traffic over a given line.

5. OPERATOR OUTPUT

In the ideal system the operator output should be as high as possible without overtaxing the human element.

6. MAINTENANCE

The maintenance of the apparatus and equipment which go to make up the ideal system should be as low as possible, but economies in maintenance should not result in corresponding loss of economy in other directions.

7. FIXED CHARGES

The fixed charges, including interest on the investment and allowances for depreciation of the equipment, should be as low as possible. As in the case of maintenance, however, economies in this direction should not be permitted to offset greater economies in other directions.

OPERATING AND MAINTENANCE CHARACTERISTICS OF THE WESTERN ELECTRIC PRINTING TELEGRAPH SYSTEMS

1. ACCURACY

It is generally conceded that mechanisms and machines are more accurate and dependable in their functioning than the most expert human operators. Perhaps this is one reason why machinery is today steadily replacing human effort in all branches of industry. Telegraphy is no exception. The best information available indicates that the undetected errors with a printing telegraph system are about one-third of the number with Morse key and sounder operation, and that of this one-third perhaps 95% are operator or line disturbance errors, and are not chargeable against the printing telegraph system. Machine accuracy is therefore of only secondary importance as compared with the accuracy of the human element since the latter cannot be entirely eliminated. In this respect perhaps the greatest factor in securing a high degree of accuracy is the time allowed the operator for checking the received messages. The Western Electric system provides ample time for this operation and in addition possesses a high degree of machine accuracy.

2. SPEED OF SERVICE

Speed of service is important from two points of view. First, it hastens the delivery of a message on which no corrections are to be made. Second, it reduces confusion at both the sending and receiving end, and thus facilitates the making of corrections. The total overall time or delay necessary for the preparation, transmission and reception of an average message (30 words) by the Western Electric system is approximately one minute. The reasons for this exceptionally short delay will be found in the few operations which are required in the handling of the traffic and in the overlapping of these operations. As regards speed of service the Western Electric system is second to none on the market.

3. FLEXIBILITY

The Western Electric printing telegraph system, which is in reality a number of systems or sub-systems, is particularly flexible in that all variations have certain apparatus units in common. Each system or sub-system is particularly suited for a particular set of traffic conditions. Through all these variations of the system there is a certain sameness in apparatus and simi-

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EFFICIENCY *in* TELEGRAPHY

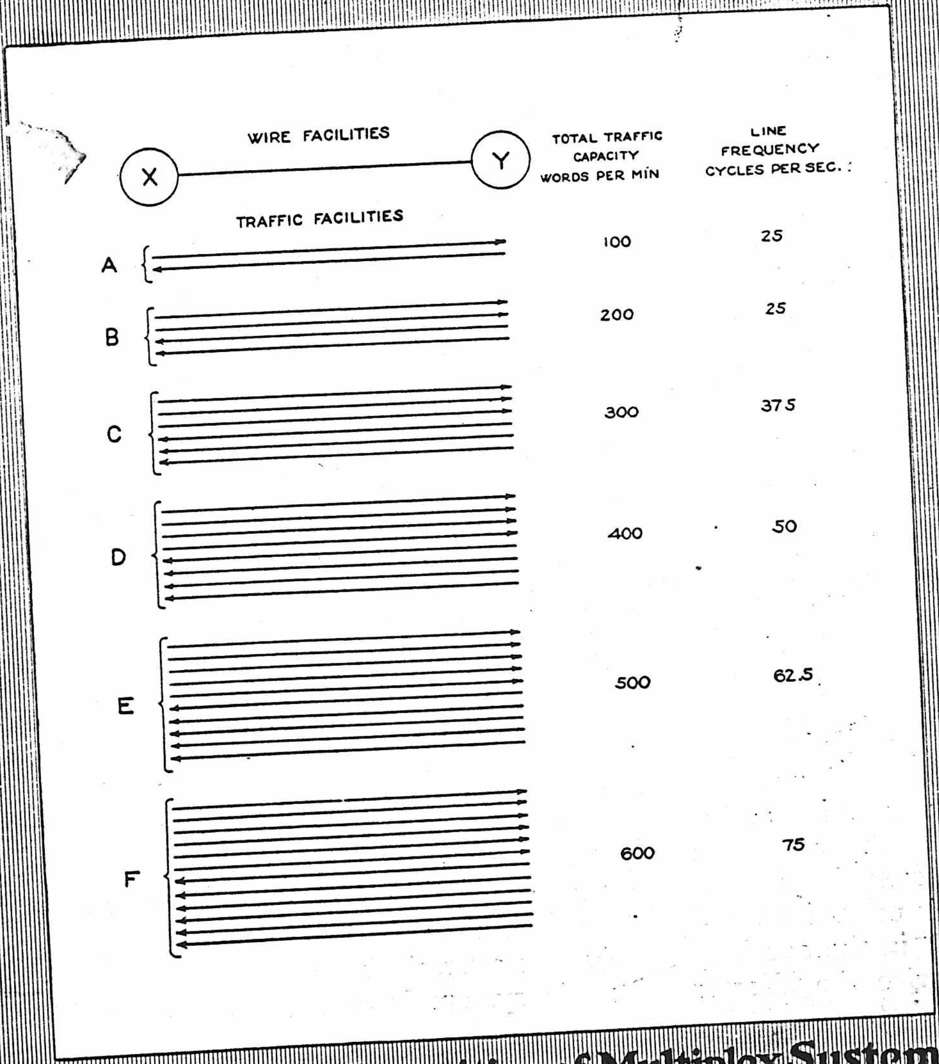

Fig 1. Single Wire Capacities of Multiplex System

iarity of circuits which tends to facilitate the matter of maintenance and operation. Further, it is possible to combine a number of these systems into one network so as to meet the special conditions and thus effect line economies not otherwise possible. In some cases circuits may be so combined as to provide for direct transmission of traffic between two points where otherwise retransmission of traffic would be necessary, thus effecting a considerable labor saving besides reducing chance for error. The possibilities in this direction are almost unlimited. Some of these combinations are explained in the following pages.

4. LINE ECONOMY

The code which forms the basis of the Western Electric system is a five unit equal letter code and is universally admitted by telegraph engineers to be the most economical, from a line transmission standpoint, for general telegraph transmission purposes. The reasons why maximum line economy can be obtained without a sacrifice in operator output are explained in the following pages and are a direct outgrowth of the flexibility of the system.

5. OPERATOR OUTPUT

The Western Electric system is so developed as to make it possible to secure maximum operator outputs without unduly pressing the human element. This results in enormous savings in the cost of labor. Just how this is accomplished to meet various traffic requirements is described in the following pages.

6. MAINTENANCE

The maintenance of the apparatus units, which make up the Western Electric system, is preventive rather than curative in nature. Periodic inspections and tests make it possible to give practically uninterrupted service. Further, the design of the various units are such that the services of highly skilled mechanics are not required. Proper maintenance is quite as important as proper design, and this fact has been given special consideration throughout the development of the system. Specific information and instructions are given regarding all adjustments so as to insure maximum margins of operation. In general, the cost of preventive maintenance will be less than the cost of curative maintenance. The maintenance of the Western Electric system is found to be a small item in comparison with the economies effected by the system.

7. FIXED CHARGES

The requirement that these charges be kept as low as as possible is inseparably tied up with the question of maintenance, operator output and line economy, since increased first cost may

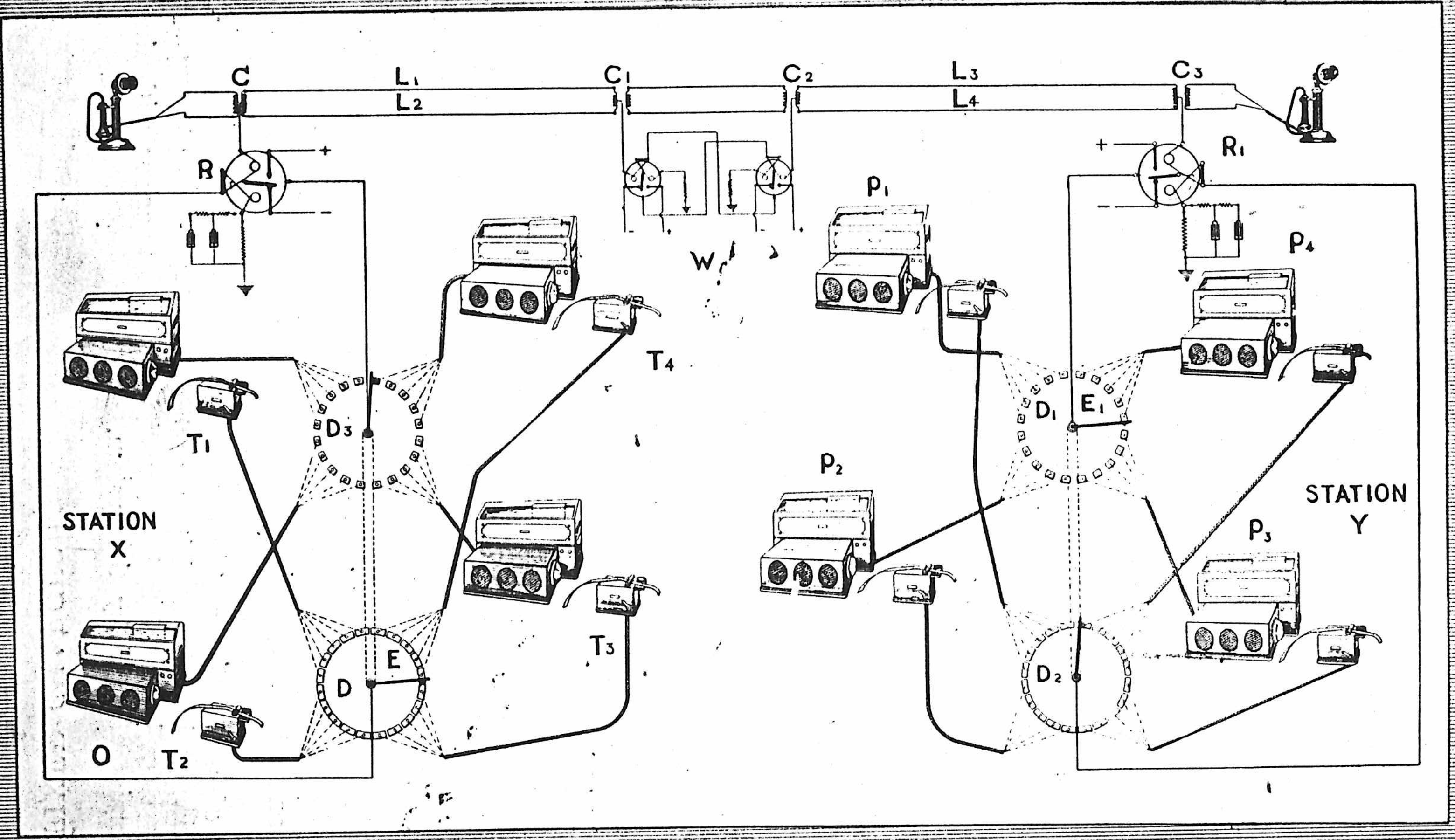

Fig 2. Schematic Picture of the Multiplex result in lower maintenance, increased operator output and a fuller utilization of the line facilities. In the development of the Western Electric printing telegraph systems it has been the aim of our engineers to produce a system or group of systems which would effect the greatest net economies. In other words, we have endeavored to provide apparatus and systems which will handle telegraph traffic at a minimum net operating cost.

Fig 2. Schematic Picture of the Multiplex

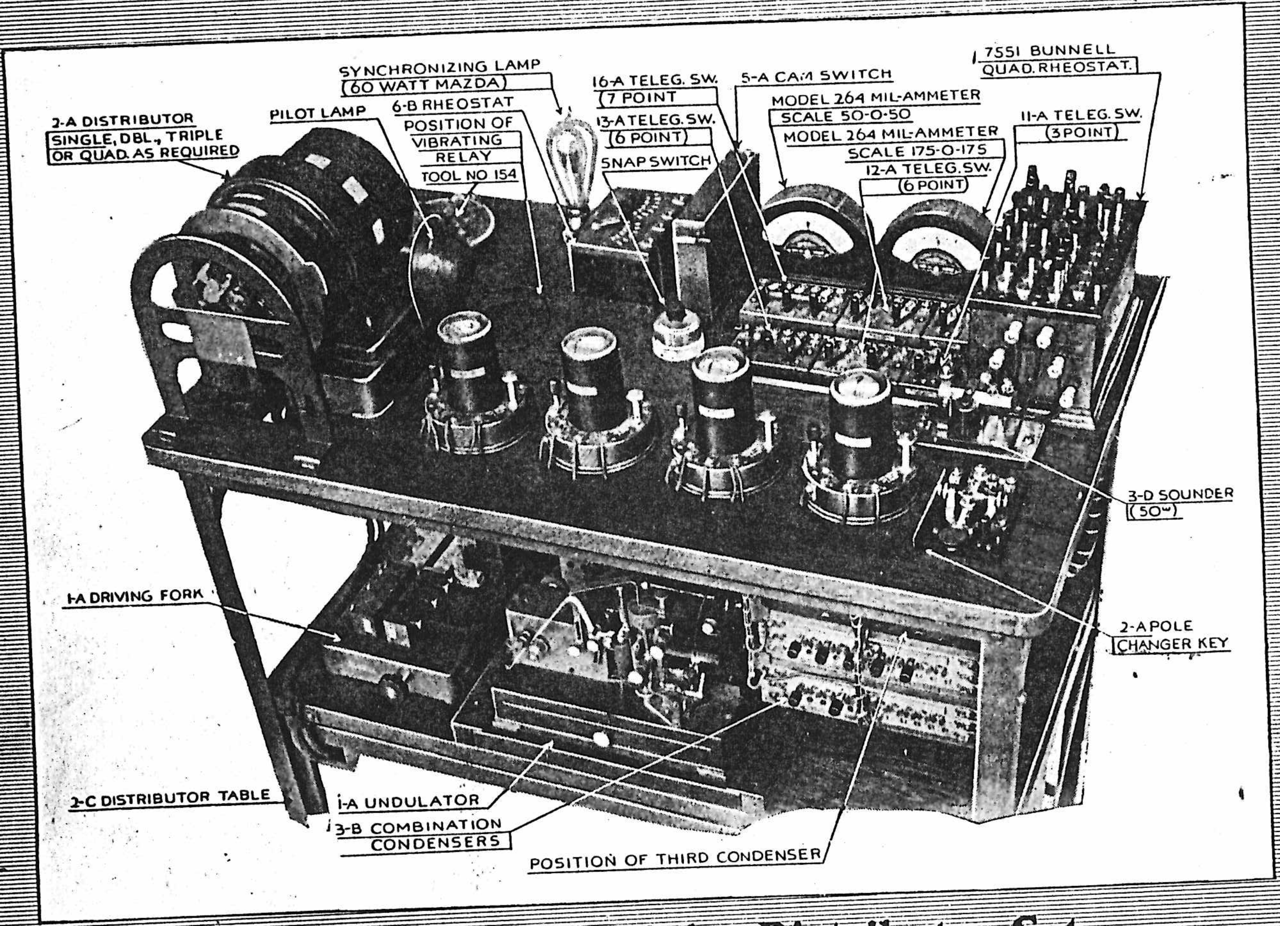
2-A DISTRIBUTOR
SINGLE, DBL., TRIPLE OR QUAD. AS REQUIRED
PILOT LAMP
SYNCHRONIZING LAMP (60 WATT MAZDA)
6-B RHEOSTAT
POSITION OF VIBRATING RELAY TOOL NO 154
16-A TELEG. SW. (7 POINT)
13-A TELEG. SW. (6 POINT)
SNAP SWITCH
5-A CAM SWITCH
MODEL 264 MIL-AMMETER SCALE 50-0-50
MODEL 264 MIL-AMMETER SCALE 175-0-175
12-A TELEG. SW. (6 POINT)
7551 BUNNELL QUAD. RHEOSTAT.
11-A TELEG. SW. (3 POINT)
3-D SOUNDER (50ω)
2-A POLE CHANGER KEY
1-A DRIVING FORK
2-C DISTRIBUTOR TABLE
1-A UNDULATOR
3-B COMBINATION CONDENSERS
POSITION OF THIRD CONDENSER

Fig 3. No. 2 Type Multiplex Distributor Set

GENERAL DESCRIPTION

Of Western Electric Printing Telegraph System

The Western Electric Printing Telegraph System is in reality a group of systems or sub-systems each of which is particularly suited to a particular set of traffic and operating conditions. These systems are suitable for operation over open wire lines, or through cables, underground or submarine, of any length, over which an electric relay can be operated satisfactorily. In other words, these printing telegraph systems are readily adapted to any type of transmission. These various sub-systems provide facilities which can be used economically to handle traffic loads varying from 600 words per minute (300 in each direction) down to 30 words per minute in either direction. They provide for transmission between two terminal stations or from one station to a number of outlying stations. This wide range in capacity for handling traffic is accomplished by varying the number of operating sets instead of increasing the speed of operation of the individual set. This makes it possible to have all sets operate at a speed which it is found secures the maximum efficiency of the operating staff. Thus it is possible to secure maximum operator efficiency as well as maximum utilization of the line facilities. These sub-systems or variations of the big system are naturally divided into two classes—Multiplex and Start-Stop.

Multiplex Systems are particularly well suited for handling heavy traffic loads or moderate traffic loads over long and expensive circuits.

Start-Stop Systems are particularly well suited for long or short line work where the traffic load does not exceed 60 words per minute in each direction. The start-stop system is also well suited for intercommunication work, new distribution, etc., where the traffic load does not exceed 60 words per minute between any two stations or between any one station and all of the other stations.

Traffic Capacity of the Various Systems

In actual practice it has been found that the maximum economic operator speed for public message business probably does not exceed 50 words per minute. This value has, therefore, been taken for computing the capacities of the various systems.

Fig. 1 shows the capacities which the various multiplex systems are capable of carrying over a single wire. The wire facilities are illustrated as a straight line connecting cities "X" and "Y." This line represents a single wire which may be a physical circuit or a derived circuit. "A" illustrates the traffic facilities when each end of the above line is equipped with a 2-A multiplex terminal equipment. Each arrow indicates a traffic

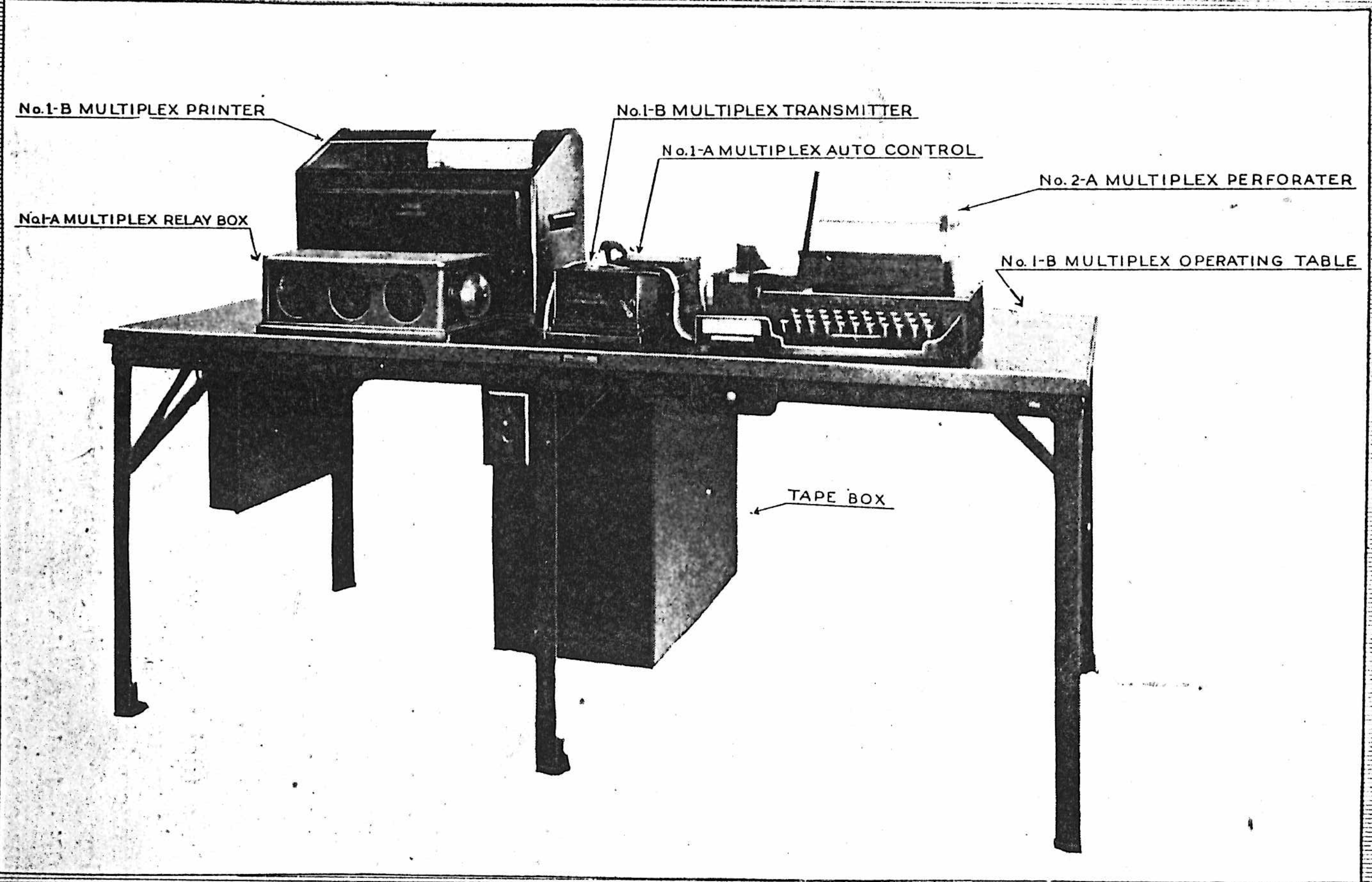
No.1-B MULTIPLEX PRINTER
No.1-A MULTIPLEX RELAY BOX
No.1-B MULTIPLEX TRANSMITTER
No.1-A MULTIPLEX AUTO CONTROL
No. 2-A MULTIPLEX PERFORATER
No. 1-B MULTIPLEX OPERATING TABLE
TAPE BOX

Fig 4. No 2-A Multiplex Operating Set

channel of 50 words per minute capacity in the direction indicated. Hence the total traffic capacity of the line so equipped is 100 words per minute. The maximum corresponding frequency of the line signals is 25 cycles per second. Likewise "B," "C" and "D" show the traffic capacities which are available if each end of the above line be equipped with a 2-B, 2-C or 2-D multiplex terminal equipment. The total traffic capacities and the corresponding line frequencies are shown in the column at the right. E and F illustrate the traffic capacities of equipment which can be furnished although none of these equipments are at present in actual commercial service. Field tests have been made which demonstrate the practicability of operating this number of traffic channels.

Bird's-Eye View of the Multiplex

Fig. 2 shows diagramatically the arrangement of the apparatus required to provide a traffic carrying capacity of 400 words per minute; 200 in each direction between cities "X" and "Y." In this particular case the operation is secured over a derived circuit, the two wires being simultaneously used for telephone purposes. Further, the distance between the two cities is such that it is thought desirable to interpose a repeater midway. The equipment shown at each end consists of 4 printers, marked P_1, P_2, etc., and 4 transmitters, T, all of which are connected to segments of a distributor or commutator. The commutators at the two ends of the line are maintained in synchronism. During each revolution of the brushes "E" of distributor "D" the signals, which correspond to one letter of four messages in transmitters T_1, T_2, T_3 and T_4, are sent to the line. These signals pass over the line through the repeater "W" and operate the relay R_1. This relay repeats the signals to the distributor D_1, whose brush E_1 distributes the signals to the printers P_1, P_2, P_3 and P_4, so that the printer P_1 reproduces the message sent by transmitter T_1, printer P_2 the message sent by transmitter T_2, and so on. The operation in the opposite direction is accomplished in exactly the same manner as that just described, the transmission in two directions being accomplished by means of the duplex balance.

The equipment at one end of this line is designated as a 2-D multiplex terminal equipment, and consists of one 2-D multiplex distributor set (Fig. 3) and four 2-A multiplex operating sets, one of which is shown in Fig. 4. Referring to Fig. 4, the sending operator is normally seated in front of the keyboard at the right (designated 2-A perforator) and writes out the message on the keys. The operation of these keys causes the perforation of holes in a paper strip which is emitted at the left of the machine. This tape then passes through the transmitter (1-B). This transmitter translates the perforations in the tape into positive and negative impulses and through the distributor 2-A (see

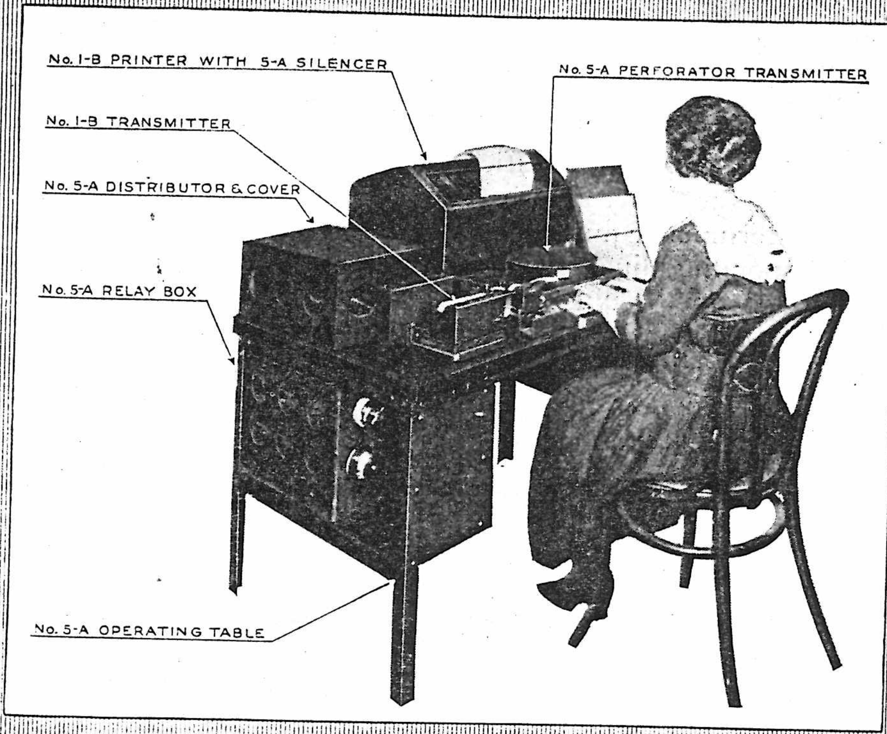
No. 1-B PRINTER WITH 5-A SILENCER
No. 5-A PERFORATOR TRANSMITTER
No. 1-B TRANSMITTER
No. 5-A DISTRIBUTOR & COVER
No. 5-A RELAY BOX
No. 5-A OPERATING TABLE

Fig 5. Nº 5-A Start Stop Operating Set

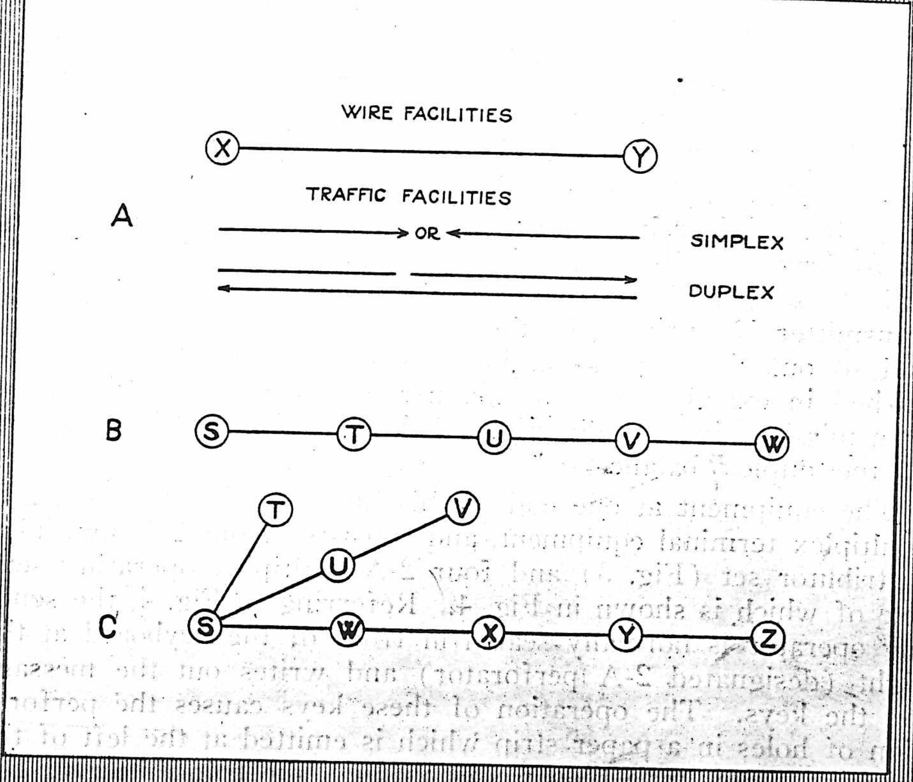

Fig 6. Start Stop Operating Arrangements & Capacity's

Fig. 3) sends the signals to line. These signals, arriving at the distant end of the line, operate a relay, which in conjunction with another 2-A distributor passes them on to the printer 1-B (Fig. 4), which translates the combination of positive and negative impulses to the corresponding letter and prints it on the paper in the machine. Thus, from each operating set (Fig. 4) we have an outgoing traffic channel and an incoming traffic channel. The messages are printed by the printer in column form on a roll of paper 8½" wide, and may be torn off after each message is completed.

The apparatus units of the operating sets are connected to the table wiring by clip connections which facilitate the removal of apparatus units for inspection and test.

Provisions for Increased Capacity

Referring to Fig. 1, it will be noted that the traffic capacity for a line equipped with 2-A multiplex terminal equipment is one-half that obtained when equipped with 2-B multiplex terminal equipment, whereas the line frequency is the same in each case [illegible] that the equipments are the same except that in the 2-A only one operating set is furnished. For this reason the use of 2-A multiplex terminal equipments is not recommended, except where there is good reason to suppose that the traffic will soon exceed the capacity of the 2-A. After a 2-A equipment has been installed it is only necessary to install an additional operating set in order to convert it into a 2-B. 2-A and 2-B equipments can likewise be converted into 2-C and 2-D by adding operating sets and making certain changes in the distributor set. The system therefore readily lends itself to gradual or abnormal expansions.

Start-Stop Operating Set

Fig. 5 shows a start-stop operating set. This set may be operated at speeds up to 60 words per minute either single or duplex. It may be worked with single or double battery, as required. When operating single the printer in front of the operator produces a home record of the messages sent. The operation of the set is very similar to that just described. This set is complete in itself in that its distributor is mounted on the table. Further, the table provides for only one operator. Working duplex it has been found that a single operator can handle both sending and receiving at speeds up to 35 words per minute, thus giving a very high operator output. In case it is desired to operate the set at a higher speed in order to handle traffic without delay at times of peak load the operator may be given assistance in the matter of handling incoming messages.

Start-Stop Circuit Combinations

Fig. 6 illustrates some of the circuit combinations for which this set is particularly suited, and also shows the traffic facili-

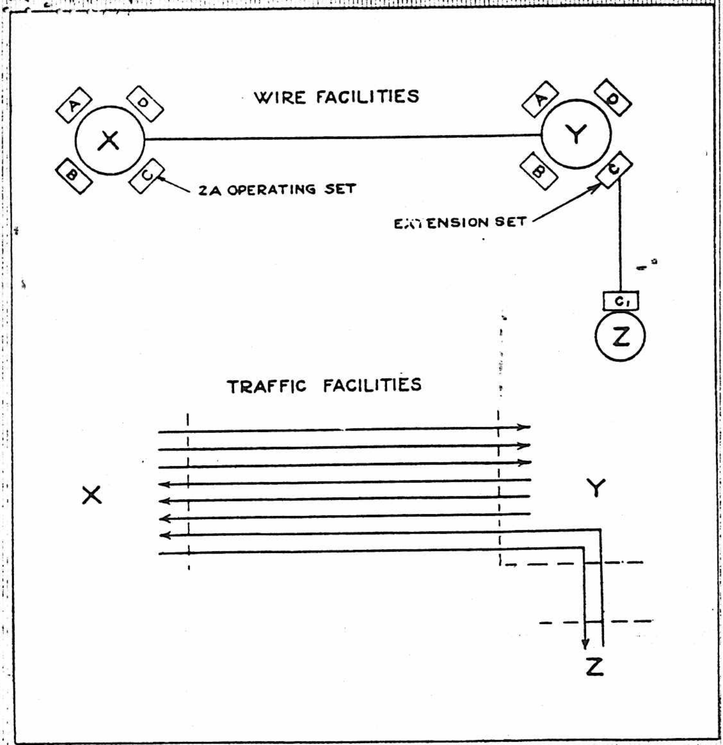

Fig 7. Extension of Multiplex Arms

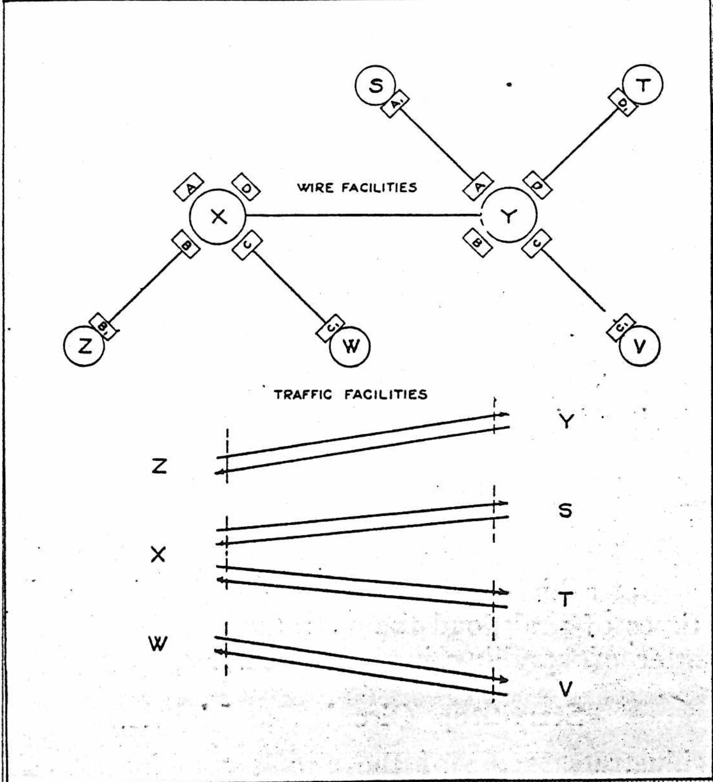

Fig 8. Combined Start Stop *and* Multiplex Operation

ties which they provide. For example, "A" illustrates a single wire between cities "X" and "Y." Two of these start-stop operating sets installed at the ends of this line would provide, if operated simplex, a capacity of 60 words per minute in either direction, or if operated duplex, 60 words per minute in each direction simultaneously. "B" shows a number of cities "S," "T," "U," "V," "W," each of which might be equipped with one of these sets to form an intercommunicating system whereby messages sent by any one will be received by all the others. This makes a very flexible system for news distribution where the quantity of traffic does not exceed 60 words per minute, since it provides means for the various out stations to talk back in case the necessity arises. For example, let us assume that "S" is normally the news distribution center. Normally, "T," "U," "V, "W" would only use a sending equipment to acknowledge receipt of items. However, "V" might suddenly become an important news center as the result of some unusual happening or disaster. The system makes it possible for "V" to send its report to all stations. The combination of cities shown at "C" could be equally well served by this system. In case it is not desired to equip the out stations with means for sending, the keyboard is omitted and a cover is provided for covering up the terminal clips, which would otherwise be exposed. Further, these sets are furnished for tape or direct keyboard sending, and for tape and direct keyboard sending. In direct keyboard sending the operation is similar to that described for the 2-A operating set except that the depression of the key determines the impulses which are to be sent to line instead of determining the combination of holes to be punched in the paper tape. In installations of the type illustrated in "B" and "C" (Fig. 6) it is not uncommon to equip station "S" with a table arranged for both tape and direct keyboard transmission, whereas the out stations "T," "U," "V," "W," "X," "Y," "Z" are equipped for only direct keyboard transmission.

Selective Calling of Out Stations

Referring again to "B" and "C" of Fig. 6, it is possible to equip these out stations "T," "U," "V," "W," "X," "Y," "Z" with selected apparatus which will enable the sending station "S" to determine which stations shall receive the message which the operator is about to send.

Extension of Multiplex Arms with Start-Stop Equipment

In addition to the variations discussed above, shown in Figs. 1 and 6, there are possibly many others which may be capable of effecting considerable economies. Some of these are purely variations of the multiplex while others are combinations of multiplex with start-stop. For example, it is possible to extend the arms of the multiplex by means of a start-stop circuit.

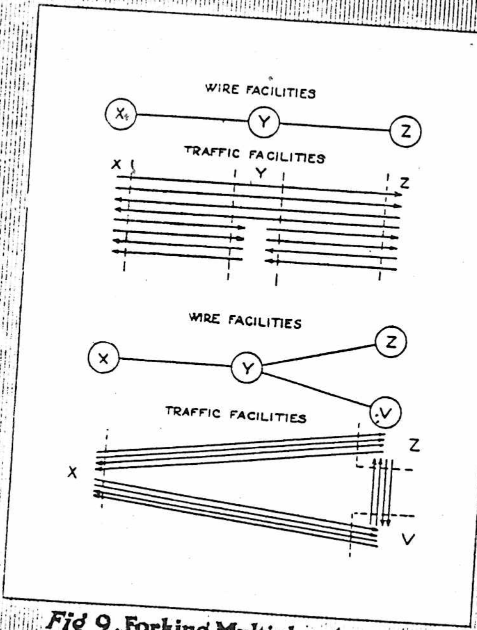

Fig 9. Forking Multiplex Arms

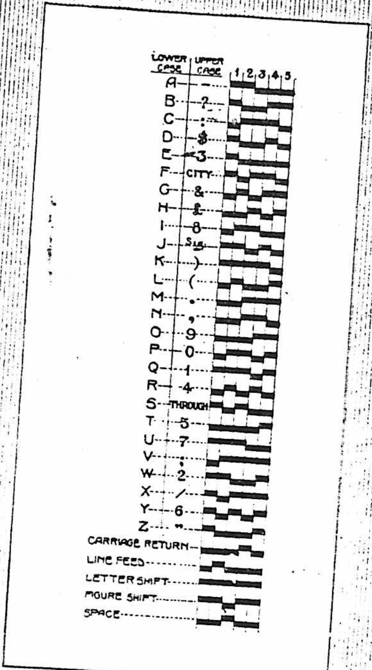

Fig 10. Five Unit Code

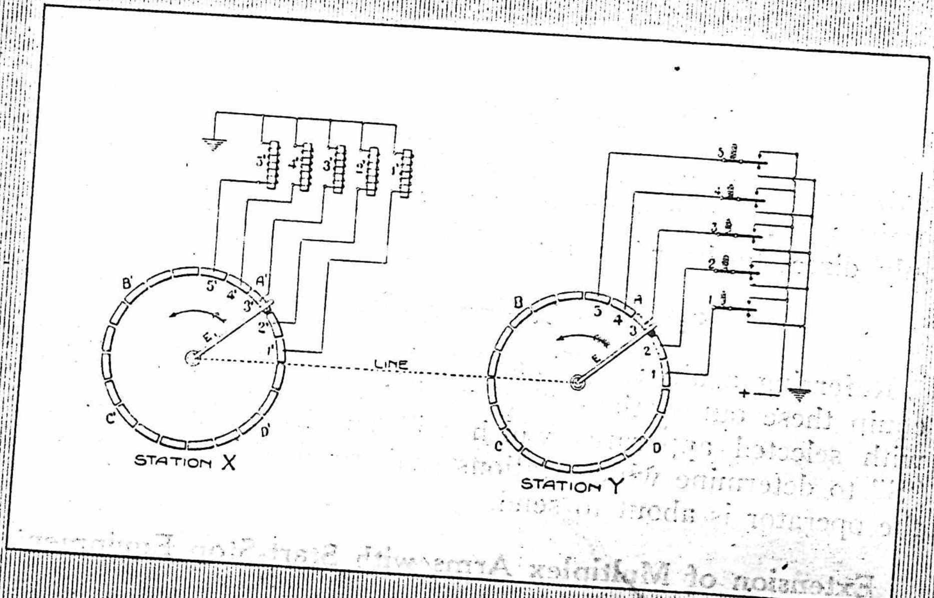

Fig 11. Theory of this Multiplex

For example (see Fig 7) let us take the case of two cities, "X" and "Y." Let us suppose that during the busy hours of the day the traffic is sufficient to warrant the installation of 2-D multiplex terminal equipments, providing a capacity of 200 words in each direction. The equipment at each end of the line would consist of one 2-D multiplex distributor set and four 2-A multiplex operating sets as shown. Suppose, further, that it is found that of the traffic between "X" and "Y," one-quarter of it is between "X" and "Z," "Z" being a third city in close proximity to "Y." One of the operating sets "C" at "Y" could be replaced by an extension set which would permit a start-stop set "C" at "Z" to work directly with operating sets "C" at "X" and thus eliminate retransmission of all messages between "X" and "Z." The arrows, therefore, indicate the traffic facilities between these cities "X," "Y" and "Z." This extension of the arms of the multiplex can be carried to the point where all arms are extended at each end. Another example is shown in Fig. 8, together with an illustration of the traffic facilities afforded thereby.

Forking Multiplex Circuits

Fig. 9 illustrates the means for combining multiplex circuits to secure maximum utilization of line plant. For example, "A" (Fig. 9) shows cities "X," "Y" and "Z." A single wire between "X" and "Y" and between "Y" and "Z" can be arranged to provide the traffic channels as shown. "B" shows another combination where cities "X," "Y," "Z," and "V" are connected, three wires radiating from "Y" to cities "X," "Z," and "V." A special distributor repeater installed at "Y" makes the traffic channels illustrated available and repeats the signals from the three outlying cities to their respective destinations without distortion.

If traffic considerations warrant, the extension of arms shown in Fig. 8 may be applied to the arrangement shown in Fig. 9. These figures serve to show the flexibility of the system. It is very likely to suppose, particularly in countries where important lines are in cable, underground or submarine, that this inherent flexibility may be used to effect large economies. Just how far it can be carried when used on open wires which are more or less subject to interruption has not yet been determined. This flexibility is effected, due to the design of the apparatus, without undue loss of time in the lining up of the distributors.

Economies Resulting from Flexibility

The economies which may be effected as the result of this available flexibility are as follows:

1. Line economy in that traffic facilities can be provided between cities without the necessity of adding additional wires.

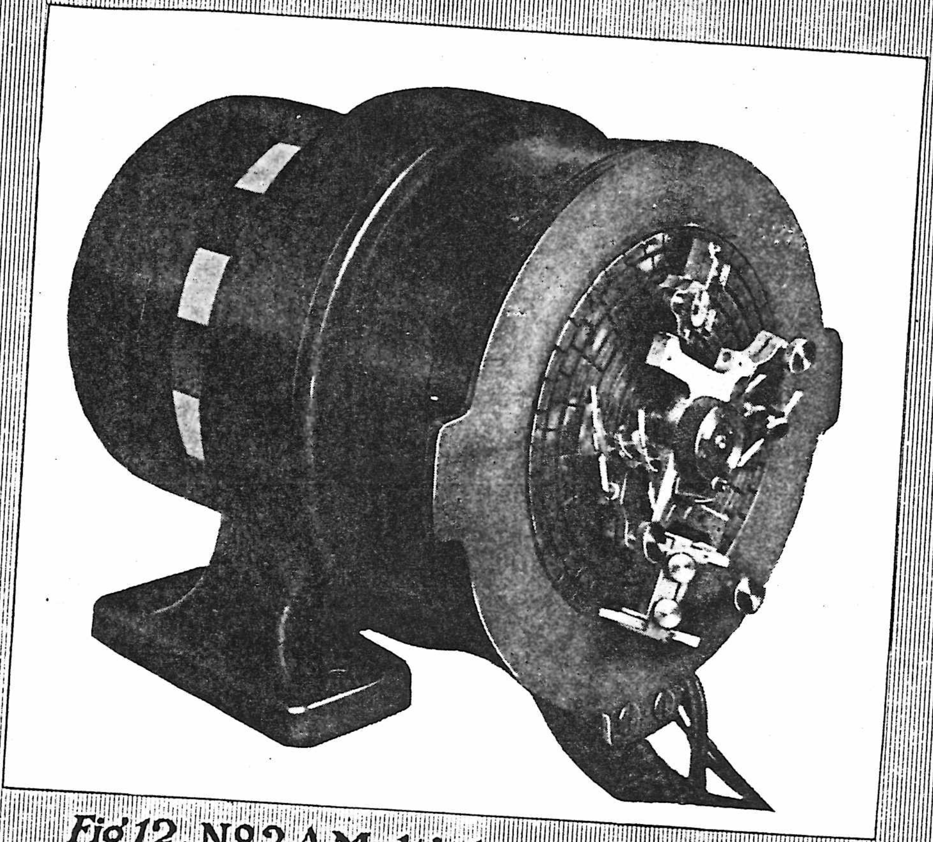

Fig 12. Nº 2-A Multiplex Distributor

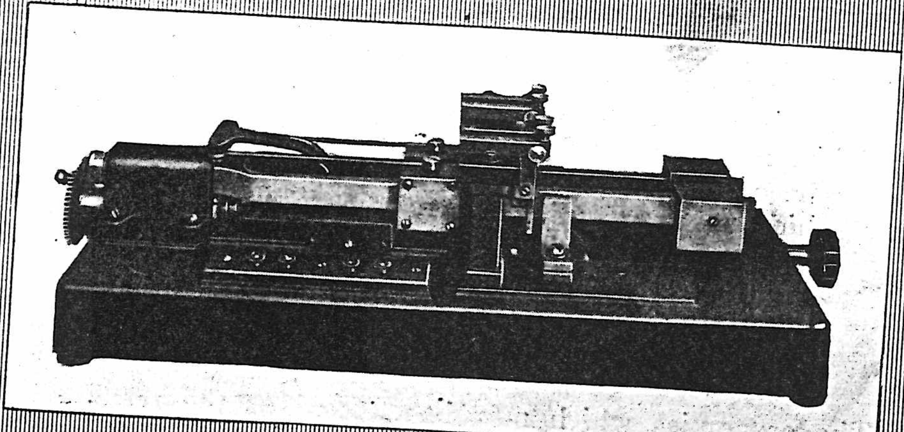

Fig 13. Nº 1-A Multiplex Driving Fork

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2. Labor economy. This results because it is possible to provide direct transmission between cities and thus eliminate retransmission of traffic. It is thought that enormous economies could be effected from this consideration alone. Still further advantages are secured by the decreased chances of error and the increased facility with which the traffic is moved.

Code

In any printing telegraph system the question of alphabet or code is one of prime importance. The Western Electric system, or systems, utilizes an equal letter or five unit code which is a modification of the Baudot code. Combinations which make up the various signals are shown in Fig. 10. Besides being particularly well adapted to the use of the multiplex principle, which is explained below, it is also the most economical as regards line time. In comparison with the Continental Morse code it compares as 9 is to 5. That is, if a given line will transmit 50 cycles per second. This code will transmit 20 letter signals whereas the Morse can transmit only 11.1 per second.

Multiplex Principle

For the purpose of explanation we will describe the quadruple multiplex. This is the type of transmission secured by the 2-D multiplex terminal equipment already described and illustrated in Fig. 2. Further, we will describe the transmission in one direction, since the transmission in the opposite direction is exactly similar, being accomplished by means of the duplex balance. Fig. 11 shows the rings of two distributors, one at station "X" and one at station "Y." Each commutator is divided into 4 sectors of 5 segments each. Station "Y" is the sending station and station "X" the receiving station. At "Y" the segments are connected to switches which determine whether the line should be connected to battery or ground. At "X" the segments are connected through relays to ground. It will now be seen if the brushes of these 2 distributors start at the same point and rotate in the same direction at the same rate of speed that when brush "E" is on segment 1 brush E1 will be on segment 1′. If at the time brush E is on segment 1 the switch 1 is raised to make contact with the battery circuit, current will flow from the battery through this switch to No. 1 segment, through brush E, over the line, through brush E1, segment 1′, through relay 1′ to ground, causing this relay to be operated. What has been said of segment 1 is equally true of the other segments. Hence it is seen that with each revolution, the brush E sends out four 5-unit signal combinations. In the actual apparatus the positions of the switch lever 1, 2, 3, 4, 5 are determined by the perforations in the tape and the perforations in the tape in turn are determined by the perforator key depressed; hence a combination of relays at "X" will be operated

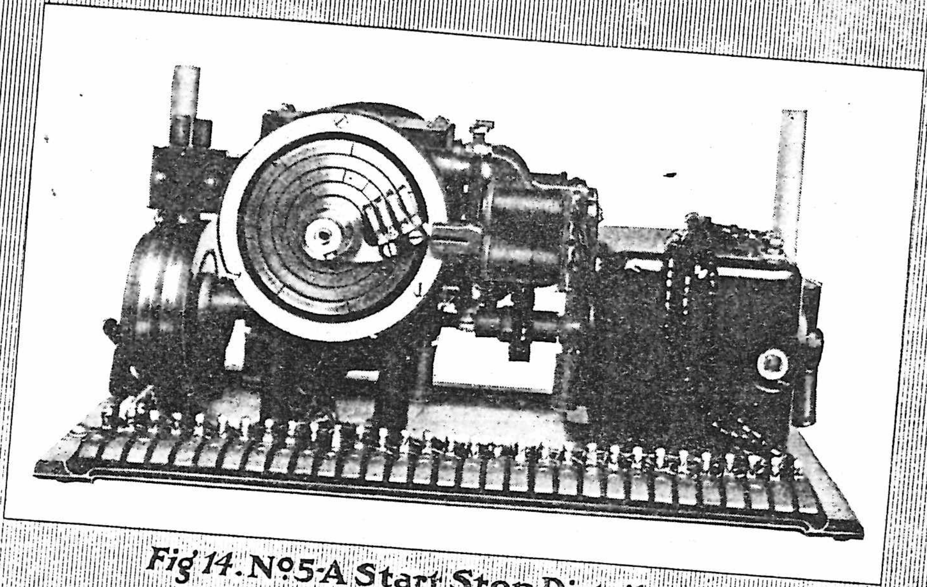

Fig 14. Nº5-A Start Stop Distributor

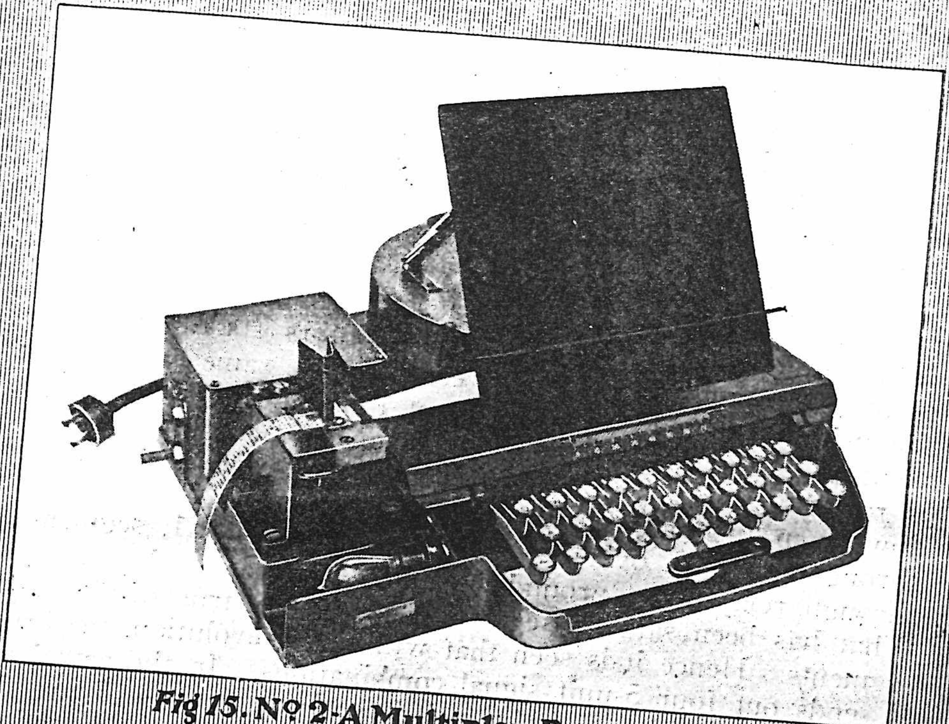

Fig 15. Nº 2-A Multiplex Perforater

corresponding to the perforations in the transmitting tape. At the receiving station these 5 relays 1′, 2′, 3′, 4′, 5′, determine the setting of a mechanism which causes the letter corresponding to the combination to be printed. The matter of maintaining these 2 distributors which may be separated thousands of miles in absolute synchronism, is an important requirement. The means employed in the Western Electric system, however, has been demonstrated to be highly satisfactory in this respect. The synchronism maintained is so good that even when operated through a number of repeaters over lines subjected to interference sufficient to badly mutilate the signals, no marked difference in the synchronism is observed. Further this synchronism is obtained without any sacrifice of line time since the signals themselves hold the distributors in synchronism.

Synchronous Repeaters

Synchronous repeaters have been developed which have a very marked advantage over the usual type of duplex repeater in that the signals are regenerated and transmitted free from the distortion. These repeaters are maintained in synchronism by means similar to that used for mantaining synchronism between the terminal distributors of the multiplex. An interesting observation in this connection is when operating through a number of these repeaters in series, the synchronism between the terminal distributors is not made less stable. Further, that this condition exists even when the signals in the various sections of the line are mutilated by induction or from other causes to the point which makes telegraph transmission impossible without considerable reduction in speed.

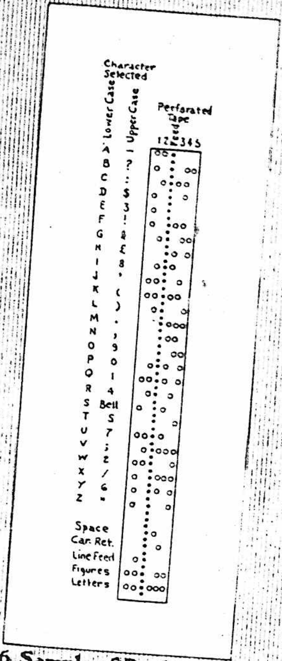

Fig 16. Sample of Perforated Tape

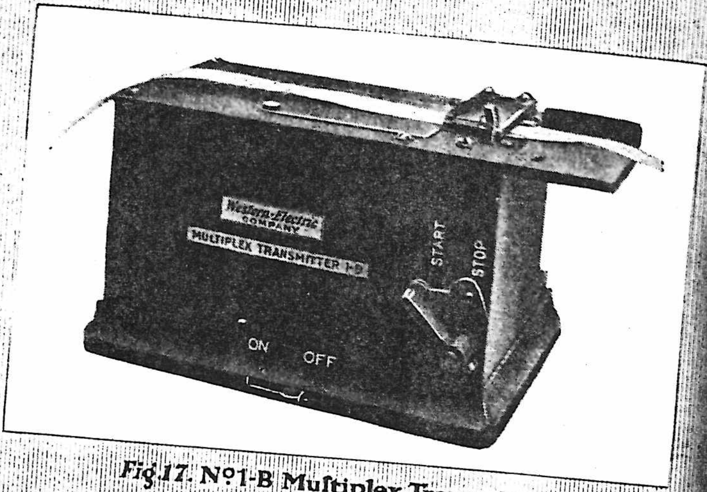

Fig. 17. Nº1-B Multiplex Transmitter

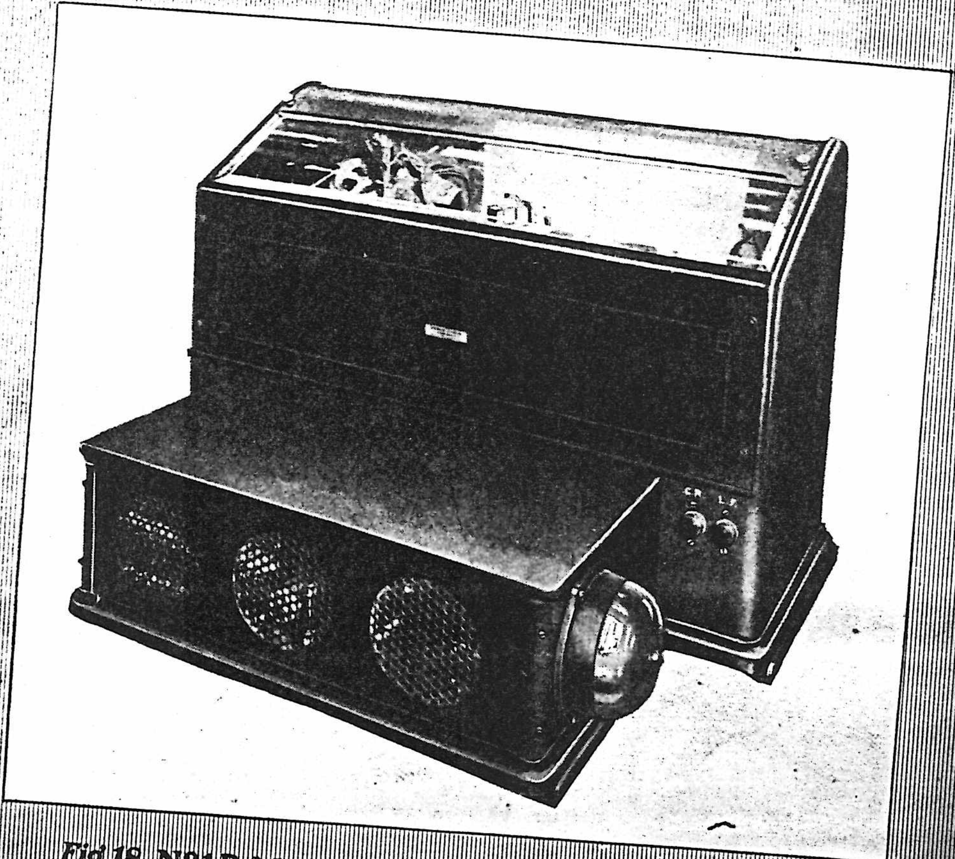

Fig 18. Nº1-B Multiplex Printer and Relay Box Nº1-A

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DESCRIPTION OF APPARATUS

Multiplex Distributor and Driving Fork

Figure 12 shows the 2-A distributor which consists of a commutator face with the revolving brush arms. The brush arms are carried by a shaft driven by a LaCour or phonic wheel motor. At the far end of the shaft is mounted a mercury flywheel which serves as a damper to prevent hunting or oscillation of the motor.

Figure 13 shows the electrically driven tuning fork. The function of this fork is to provide impulses for driving the distributor. The speed of the motor is determined by the rate of vibration of the fork which possesses a high degree of constancy. This fork and the distributor of the type shown in Fig. 12 are used in the multiplex systems and for synchronous repeaters.

Start-Stop Distributors

Figure 14 shows the 5-A distributor. This differs from the multiplex distributor 2-A, shown in Fig 12, in that it is driven by an ordinary direct current shunt motor, the speed of which is accurately controlled by a sensitive governor. This distributor has two faces, the receiving face on one side and the sending on the other. In its operation this distributor differs from the 2-A in that its brush arms are not constantly rotating with the motor shaft. In this case, the brushes are connected to the shaft through flexible couplings and are maintained stationary by a stop controlled by a magnet. The operation of this magnet withdraws the stop and permits the brush to make one complete revolution. While this results in a certain loss of line economy in that the code virtually becomes a seven unit code, it possesses the advantage that it permits of intercommunication.

It is the starting and stopping of the brush arms which gives the distributor and system its name "Start-Stop."

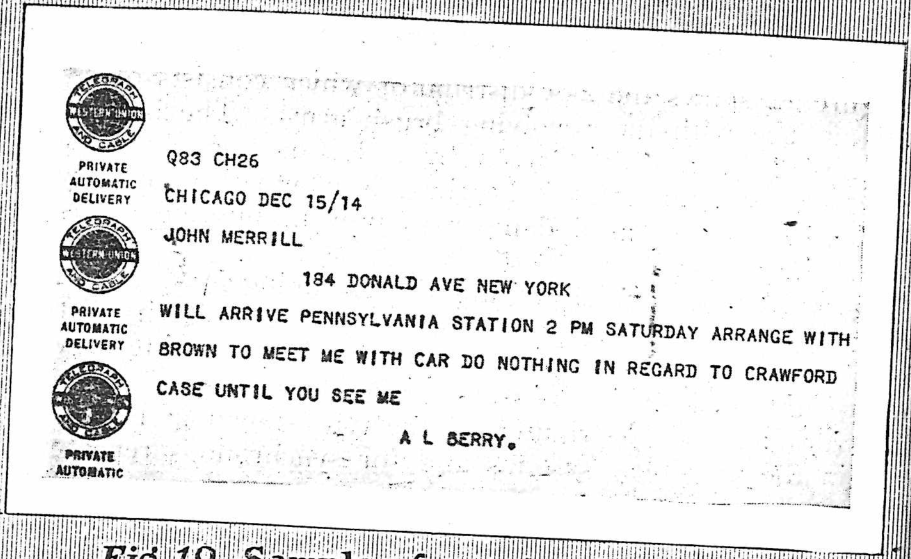
Perforator

Fig. 15 shows the perforator. This apparatus is provided with a keyboard similar to that of a standard typewriter. The operation of keys determines the selection of punches which will be operated to perforate the desired combination in the tape.

Fig. 16 shows a sample of the tape, each series of cross-perforations representing a signal character. Below each perforation is written the character or function corresponding to that particular combination. A back space key is provided which permits the operator to make corrections in the tape.

Tape Transmitter

The tape transmitter is shown in Fig. 17, with a piece of tape in position. This is the instrument which translates the combina-



PRIVATE AUTOMATIC DELIVERY

Q83 CH26

CHICAGO DEC 15/14

JOHN MERRILL

184 DONALD AVE NEW YORK

WILL ARRIVE PENNSYLVANIA STATION 2 PM SATURDAY ARRANGE WITH BROWN TO MEET ME WITH CAR DO NOTHING IN REGARD TO CRAWFORD CASE UNTIL YOU SEE ME

A L BERRY.

Fig 19. Sample of received message

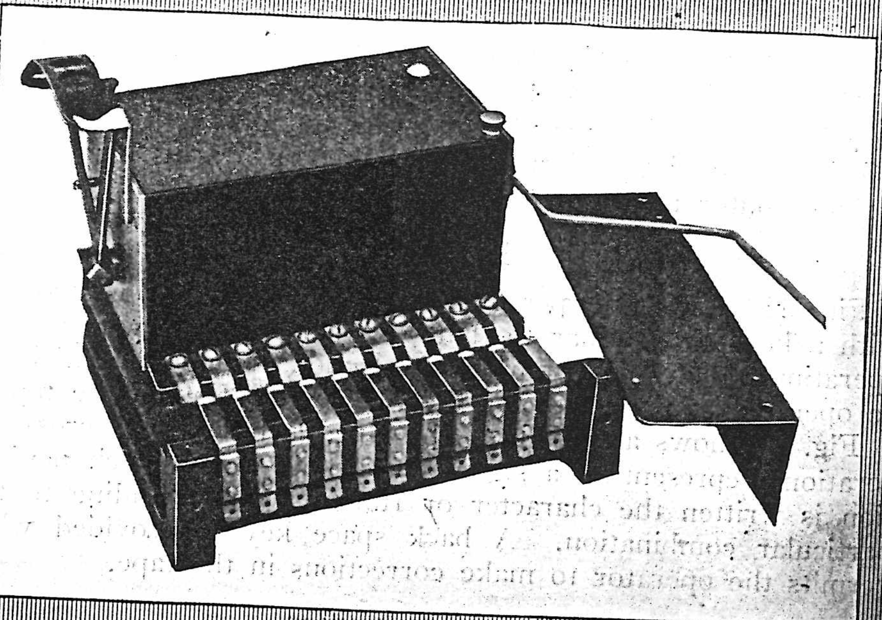


Fig 20. No 1-A Multiplex Auto Control

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tions of perforations into combinations of positive and negative currents. As the tape passes through the transmitter, five pin feelers feel out the tape. These pins in turn control five levers which are connected to five segments in the sending ring of the distributor. These levers make contact with positive or negative battery as the corresponding feeler pin finds a perforation or no perforation.

Printer

The 1-B printer and its associated 1-A relay box are shown in Fig. 18. It is also shown on the multiplex operating set in Fig. 4. In the start-stop operating set, Fig. 5, the same printer is used but the 1-A relay box is not used. The printer is one of the movable paper carriage type. A sample of the message produced is shown in Fig. 19. Printing is accomplished by forcing the paper against the type wheel. This type wheel is mounted on a shaft which is maintained under constant torque by a spring. When a letter signal is received the type shaft is released and the wheel revolves until it engages a stop which brings the required letter in front of the paper. Buttons are provided which make it possible for the receiving operator to feed up the paper or return the carriage at will. Messages are torn off just above the glass window on a steel cutting edge. A small crank is sometimes furnished at the left hand end of the printer to permit the operator to feed up the paper more rapidly. The type of message form shown has an advantage of economy in paper. It has a further advantage that only one piece of paper is required per message, regardless of the length of the message.

Auto Control

The auto control, Fig. 20, is an auxiliary piece of apparatus not fundamentally required in the Multiplex System, but which serves two very useful purposes. First, it automatically stops the feeding of the tape through the transmitter, providing the perforator operator does not produce the tape as fast as it is required. It thus allows the tape to be fed directly from the reperforator. Second, it serves to send the special signals required to operate the bell on the distant printer without removing the tape from the transmitter, or mutilating the message that is being transmitted. Fig. 20 also shows the clip connections used on the Western Electric Multiplex apparatus.

Facilities for Maintaining Equipment

With each multiplex terminal equipment there is usually furnished a test table shown in Fig. 21. This table is equipped with a complete set of apparatus, including perforator, transmitter, printer and auto control. The table is also provided with a test distributor, which makes it possible for the maintainer to simulate operating conditions and thus test and ad-

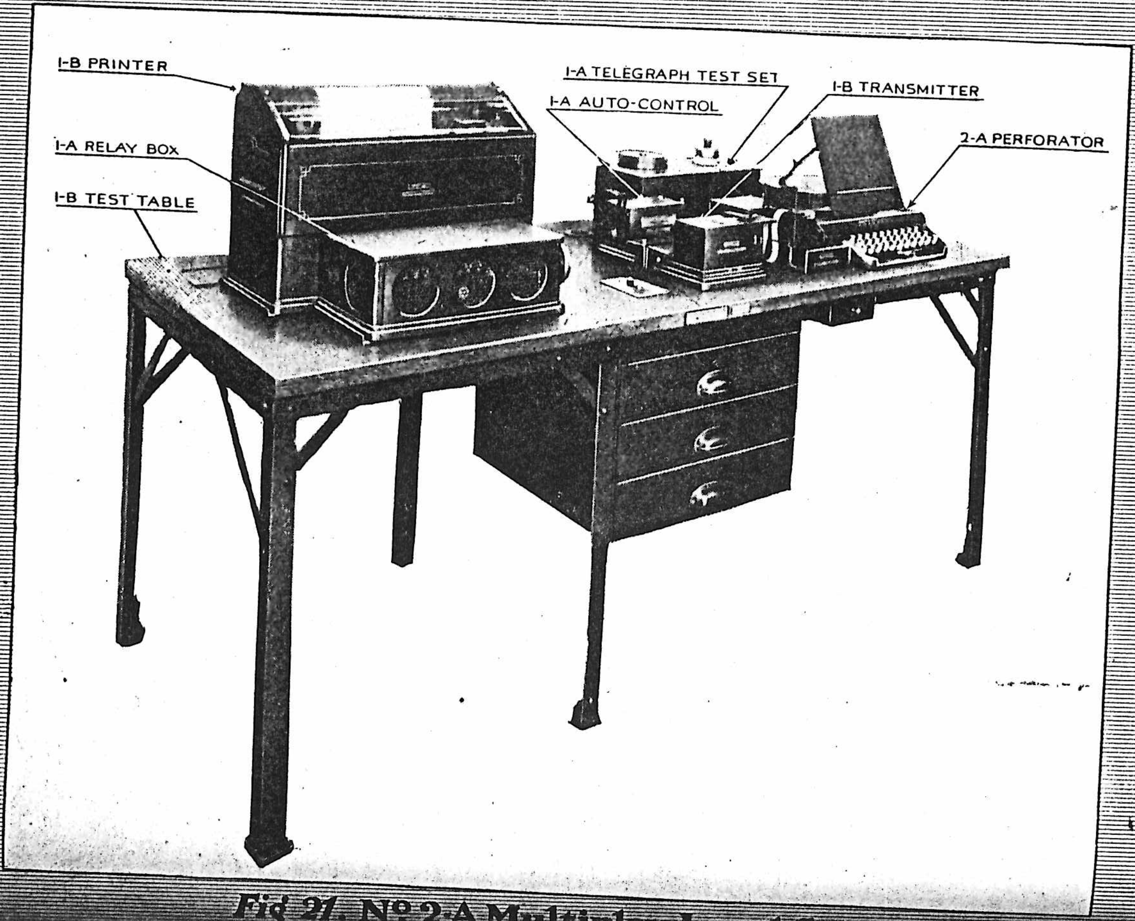

Fig 21. No 2-A Multiplex Local Set

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just the various apparatus units. This arrangement makes it possible to install regular inspection routine. For example, at intervals each piece of apparatus is taken to the test table and replaced by a similar piece of apparatus taken from the test table. This work is also facilitated by the fact that these apparatus units make clip connections to both operating and test table.

Power Supply

All of the Western Electric printing telegraph apparatus is designed to operate on 110 volt direct current, but considerable attention has been paid in the design of this apparatus to allow of good operation and voltages varying from 90 to 125 volts. In installations, which consist of only one start-stop set or a 2-A multiplex terminal equipment, a current capacity of 3 amperes would be sufficient for proper operation, but owing to the extra current required for testing, table lamps, soldering irons, etc., it has been found advisable not to have a capacity of less than 6 amperes for any single installation, with a proportionate increase for installations of more than one set.

Western Electric Printing Telegraph Apparatus

The following tables give the apparatus required to make up the various printing telegraph sets.

TABLE 1
COMPOSITION OF MULTIPLEX TERMINAL EQUIPMENTS

Designation of Composition Sets	Amounts Required for Complete Equipment of One Terminal			
	2-A Multiplex Terminal Equipment Single	2-B Multiplex Terminal Equipment Double	2-C Multiplex Terminal Equipment Triple	2-D Multiplex Terminal Equipment Quadruple
2-B Multiplex Distributor Set Double	1	1	0	0
2-C Multiplex Distributor Set Triple	0	0	1	0
2-D Multiplex Distributor Set Quadruple	0	0	0	1
2-A Multiplex Operating Set	1	2	3	4
2-A Multiplex Local Set	1	1	1	1
Set of Printer Tools	1	1	1	1
Set of Spare Parts	1	1	1	1
Set of Stationery	1	1	1	1
Maintenance Instructions	1	1	1	1
Catalog of Parts	1	1	1	1

TABLE 2
COMPOSITION OF MULTIPLEX DISTRIBUTOR SETS

Designation of Units	Number of Units Required for One Set		
	2-B Multiplex Distributor Set Double	2-C Multiplex Distributor Set Triple	2-D Multiplex Distributor Set Quadruple
2-C Distributor Table	1	1	1
2-A Distributor	1 double	1 triple	1 quadruple
1-A Driving Fork	1	1	1
210-A Relay (Polar)	4	4	4
3-B Combination Condenser	2	2	2
No. 7551 Quad. Rheostat	1	1	1
Weston Model No. 264 Mil-Ammeter 50-0-50	1	1	1
Weston Model No. 264 Mil-Ammeter 175-0-175	1	1	1
1-A Undulator	1	1	1
Sets of Units for Vibration Circuits	1	1	1

The last two items are furnished only in special cases

EFF

Name a

1-B O

2-A Pe

1-B Tr

1-A Au

1-B Pr

1-A Re

1-A Te

1-B Te

Transn

Speed

Compo

Operati

Operati

Copy

Relay

Distrib

Distrib

Distrib

Telegra

Printer

Silencer

Clip Co

Perfora

Keyboa

Telegr

TABLE 3
COMPOSITION OF THE MULTIPLEX OPERATING AND LOCAL SETS

Name and Code of Units	Number of Units Required for One Set 2-A Multiplex Operating Sets	 2-A Multiplex Local Sets
1-B Operating Table	1	0
2-A Perforator	1	1
1-B Transmitter	1	1
1-A Auto Control	1	1
1-B Printer	1	1
1-A Relay Box	1	1
1-A Telegraph Test Set	0	1
1-B Test Table	0	1

TABLE 4
COMPOSITION OF START-STOP SETS

Code Designation	5-A Private Telegraph Set	5-B Private Telegraph Set	5-C Private Telegraph Set	5-D Private Telegraph Set	5-E Private Telegraph Set	5-F Private Telegraph Set
Transmission	Tape and Keyboard		Keyboard Only		Receiving Only	
Speed Range Words per min	25 to 50	40 to 60	25 to 50	40 to 60	25 to 50	40 to 60
Component Units	Quantities of Apparatus required for one set.					
Operating Table No. 5-A	1	1	0	0	0	0
Operating Table No. 5-B	0	0	1	1	1	1
Copy Holder No. 5-A	1	1	1	1	0	0
Relay Box No. 5-A	1	1	1	1	1	1
Distributor No. 5-A	1	0	1	0	1	0
Distributor No. 5-B	0	1	0	1	0	1
Distributor Cover No. 5-A	1	1	1	1	1	1
Telegraph Transmitter No. 1-B	1	1	0	0	0	0
Printer No. 1-B	1	1	1	1	1	1
Silencer No. 5-A	1	1	1	1	1	1
Clip Cover No. 5-A	0	0	0	0	1	1
Perforator Transmitter No. 5-A	1	1	0	0	0	0
Keyboard Transmitter No. 5-B	0	0	1	1	0	0

Telegraph Relay No. 24-B and Relay Cover No. 5-A are included in special cases.

537.813 5300

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CHAPTER VII

PAGE

High-capacity systems—Classification—Automatic systems—Murray—Creed—Multiplex systems—Line multiple methods—The Baudot—Repeaters—Echelon working—Radio printing systems—The Murray—The American multiplex—Rotary repeaters—Reversible working—Automatic *versus* multiplex 330

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CHAPTER I

Introductory—The elementary printing telegraph—Time and space signals—Space signalling telegraphs—Selective methods—The step by step system—Telegraph alphabets based on principles of numeration—The five-unit alphabet—The three-unit alphabet—Methods of telegraphing three- and five-unit alphabets—Collection and distribution of time signals—Signal storage—The locked keyboard—The cadence signal—Translation of time into space signals—Multiple operation—Types of signalling impulse—Cable Morse—Landline Morse—Stenocode—Necessity for double-current working—Disadvantages of two-power method of signalling—Eight-unit and eleven-unit alphabets—Comparison of equal and unequal letter alphabets—Order of frequency of letters in different languages—General principles involved in the composition, transmission, reception, and translation of a printed telegram.

ONE of the most striking facts revealed by a complete survey of the art of printing telegraphy is the enormous amount of ingenuity devoted to invention while telegraphy was still an art in embryo.

This at once arouses the student's admiration and his regrets for the unrewarded work of those who have gone before us.

In this quickly moving age it is not uncommon to see an entirely new art spring up in a few years from the position of being an interesting curiosity, the product of the scientist's laboratory, to a highly developed commercial stage, involving millions of invested capital, and employing thousands of people in its development, manufacture, and exploitation.

Wireless telegraphy will readily suggest itself to the reader as an example of this tendency.

Printing telegraphy, on the other hand, is only becoming an industry after most inventors' rights have ceased.

Printing telegraphy owes its present position very largely to the pioneer work of Jean Maurice Emile Baudot, an officer of the French Telegraph Service, who practically devoted the whole of his life to the development of the system which bears his name.

The Hughes' Printing Telegraph, developed during 1855–1863, was widely used, prior to the advent of the Baudot, on all important lines in Europe; but the last ten to fifteen years has seen the Baudot and other equal letter systems making their way steadily in all countries of the world. This is almost entirely due to the employment of the five-unit code, the shortest practicable code for land lines. Thus the utmost possible use is made of the transmission capabilities of the line, since not only are the letters short with respect to line time, but no space element is necessary between letters in an equal letter code. The equal letter feature of an alphabet leads also to simplicity in the mechanisms involved.

The multiple principle adopted by Baudot secures convenient methods of handling and distributing traffic, and at the same time results in the working speeds of unitary mechanisms being comparatively low—four to five cycles a second only.

Neither the five-unit code nor the multiple principle were invented by Baudot. The five-unit code was proposed for telegraphy by Gauss and Weber (1833); was used by Whitehouse (1853–1854); and proposed by W. H. Burnett for a multiple system in 1860.

Multiple channel working by division of the line time was patented by Moses G. Farmer in 1853, while more complete proposals, including locked keyboards and a cadence signal, were due to Burnett, cited above.

Baudot took, as he was perfectly entitled to do, known elements and combined them, producing a practical multiple system of printing telegraphy. If he had done nothing more than this, he would still be entitled to the lion's share of the credit in the evolution of the modern multiplex printing telegraph; but in point of fact, he did a great deal more. He invented a number of ingenious "translators" or printers, and devised methods of maintaining synchronism between remotely situated rotary organs, and he developed distributing apparatus which remains standard to-day in nearly all its details. It seems curious that in the land of his birth a complete record of his work has never been revealed, although it stands on the shelves of the Bibliothèque Nationale at Paris for all to read.

I gather the following particulars of his career from a paper entitled "The Baudot Telegraph System," by A. C. Booth, and read in 1907 before the Institution of Post Office Electrical Engineers.

Baudot was born at Magneux on September 11th, 1845, and entered the French Telegraph Service on July 16th, 1870. In 1872 he endeavoured to combine the Hughes' printing telegraph with the multiplex system of Meyer (1871), and he adopted the code of Gauss and Weber. His electrical receiver was produced in 1874. Baudot's means were too slender to allow him to develop his ideas, and in 1875 he submitted his invention to the French Administration. In June, 1875, the French authorities accepted his proposals, and the first trial took place that year. A quintuple set was then made, and in 1877 the system was officially adopted. He devoted the whole of his time and energy to the improvement of his invention, supplementing the official grant to such an extent that he had to pledge the gold medal awarded to him at the International Exposition of 1878.

He was promoted to the Légion d'Honneur in 1879, and obtained a diploma of honour at the Paris Electrical Exposition of 1881. He was made an inspecting engineer in 1882, and died on March 28th, 1903.

It is not too much to say that his influence on printing telegraph design has been profound. Scarcely any designer to-day can avoid embodying some detail which did not originate with Baudot. Every printing telegraph inventor using sliding notched permutation bars or discs has adopted a device of Baudot's. The permutation

escapements used in some special makes of typewriter saw the light for the first time in one of Baudot's early patent specifications.

One could go on multiplying examples of this character, but perhaps the most striking is the Rowland printing telegraph system. The Rowland translating device was identical in principle with the electrical translator which Baudot invented in the early stages of his development work. Rowland adopted page printing in place of tape, and the duplex balance to secure two-way working. Baudot always kept to the simple tape printer, but was the first to suggest the application of the duplex balance to equal-letter multiplex systems, which he did in his British Patent Specification 436 of 1882.

If Rowland had copied Baudot in his choice of an alphabet his system would possibly have had a longer life.

The Murray Automatic System, a high-speed one-channel printing telegraph, emerged 1899–1901, and about the same time Siemens and Halske brought out an automatic system, using the Rowland alphabet and photographically recording the signals.

The Buckingham Automatic System appeared 1900–1902. 1903 saw the "Autoplex," a multiple system designed by Murray. This was the forerunner of the modern multiplex, providing for page printing, keyboard perforators, automatic transmitters, and automatic stop and start, while two-way working was secured by the duplex balance.

The high-speed Morse code printer, invented by Creed, had already appeared, and the period 1899–1905 may be termed the Renaissance period of printing telegraph invention.

The foregoing is a brief record of the steps in the evolution towards the modern high-speed printing telegraph, and the innumerable details which have been added to the skeleton formulated by Moses Farmer in 1853 and carried further by Burnett in 1860 will appear as the reader proceeds.

The mechanism employed in any given system of printing telegraphy will be found to consist of a combination of known parts, arranged in a manner to some extent depending upon the code used to differentiate the various letters from one another.

The simplest form that a printing telegraph can take is that diagrammatically indicated in Fig. 1. Two stations, A and B, are connected by a line wire L. A transmitter key K is adapted when depressed to connect an earthed battery to the line. At the receiving end an electro-magnet, PM, when operated, moves a paper tape against a revolving inked type wheel TW, on the rim of which the letters of the alphabet, figures, and other signals are provided in the form of raised type surfaces. The letter opposite the tape at the moment the magnet is operated is thus imprinted. The correct selection of the letter depends upon the transmitting key K being actuated at the right instant of time, during a single revolution of the type wheel at B. To ensure this an indicator disc or a similar type wheel is provided at A. The two wheels must also run at the same speed and be in phase, *i.e.* occupy the same position in space, that is, they must be in *synchronism* with one another. In practice the type wheel at the receiving station will have to be adjusted from the theoretical position by a slight angle, and in a direction opposed to that of rotation, due to the fact that a small but measurable time

Disturbances affect the two coupled circuits equally or approximately so, and false signals are eliminated. Also, the relay does not require biassing to space, but can be set in its most sensitive condition.

Quadruple duplex transmission and reception has been carried out on these lines, separate receiving and transmitting aerials, linked by land lines as is standard duplex wireless practice, being employed.

The Siemens and Halske high-speed automatic has also been successfully used for wireless traffic at 600 letters per minute. All these experimental trials have revealed that the necessary synchronism can be maintained even with prolonged atmospheric disturbance or "jamming," false letters only being caused. Traffic has also been carried on between London and Berlin at 300 letters per minute between 3 to 8 p.m. daily with a 5 KW valve transmitter at Koenigswusterhausen and an arc at Stonehaven.

The valve amplifier makes it possible to use any form of printer or recorder, and Creed working is possible with the same ease as the five-unit system.

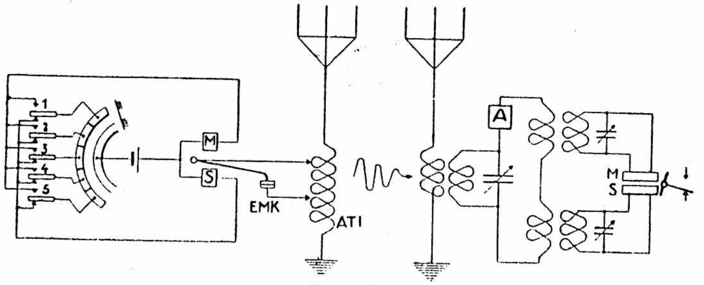

FIG. 386.

The five-unit system has an apparent advantage over Morse in that it is practically impossible to tap it. The would-be listener would have to synchronize his apparatus, and would be minus the usual means for ascertaining when he is coming in or going out of phase.

When we can be sure that radio methods can be applied as successfully as land lines or cables to the telegraphic traffic of the world, the machine telegraph can supplant manual methods as readily as it does so at present with wire communication.

In a paper on "Imperial Telegraph Communications," read by F. J. Brown, C.B.E., before the Telegraph and Telephone Society of London, on October 17, 1921, it is stated that the capital cost of a pair of long-distance wireless stations is considerably less than that of a cable. The rate of depreciation and the engineering cost of working is greater, and it still has to be proved that the whole of the annual expenses are very much less in the one case than in the other.

Prolonged disturbance is the bugbear of long-distance radio communication. So long as high speed transmission is only possible for a fraction of the twenty-four hours, so that the average rate of transmission is lower than that of a trans-Atlantic cable worked by modern methods, cables will continue to be laid. When the loaded cables at present projected are laid, and provided that they come up to expectations, trans-oceanic radio links will fade into the background, unless the large and ever-growing band of workers in this field solve the problems of rendering them immune to disturbance. It is interesting to note how the two branches of the art of communication re-act on one another. The intrusion of radio into the long distance field has put the cable engineers on their mettle, and the loaded cable is likely to result. We can expect that its arrival will still further stimulate research work in radio circles.

If only disturbance could really be overcome, radio communication would offer solutions in the disposal of the world's traffic far in advance of those rendered possible by fixed or invariable links.

The British Post Office have, during the last few years, extended the use of the Baudot to their inland trunk telegraph circuits.

The main differences between the British and the French systems are those of methods, the apparatus, except for slight variation of details, remaining the same.

Due to the stability of the English trunk wires, duplex working is adopted, whereas in France, except for one or two Anglo-French wires and the Mediterranean cables, simplex working is invariable. Duplex working doubles the capacity of a circuit, while it also obviates the need for propagation contacts, thus saving from 10–15 per cent. of line time. Fig. 387 sets out the main details of a quadruple-duplex circuit arranged on British Post Office lines. It hardly requires any explanation. Outgoing signals pass from rings R 2 and R 5 through switch S 1 to the differentially wound line relay. A branch circuit is taken through a leak resistance LR and leak relay LK.R, the latter repeating via rings R 1 and R 4 to a set of "control" printers. Incoming signals are repeated by the line relay to the receivers shown at the right of the diagram. A branch circuit is taken through S 2 and a resistance to a Wheatstone receiver and sounder. S 2 enables outgoing signals to be checked when required, while a Morse key can be introduced by suitable manipulation of S 1.

The British Post Office have also introduced duplex-echelon or "split-duplex" circuits, and have carried the multiplex principle as far as sextuple duplex. Correction is generally effected on the Baudot plan, but phonic wheel motors with speed correction have been in use for some time.

The substitution of keyboard perforators for the usual manipulator is about to commence, due to the ingenious solution of the Baudot perforator problem effected by Messrs. Booth & Willmott.

As has been previously pointed out, the assignment of letters and figures on the Baudot printer does not agree with that of the Universal Keyboard. With the ordinary typewriter Q and 1 appear on the same key, and represent the upper and lower case characters assigned to that key. On the Baudot printer 1 is the inversion of A. If we wish to retain the universal keyboard, we must arrange that when a shift is made from either case to the other, the appropriate letter signal combination is made.

Booth and Willmott's method of securing this is set out diagrammatically in Figs. 388 and 389. The key levers act on five differentially toothed tee levers TL suspended on a parallel link work.

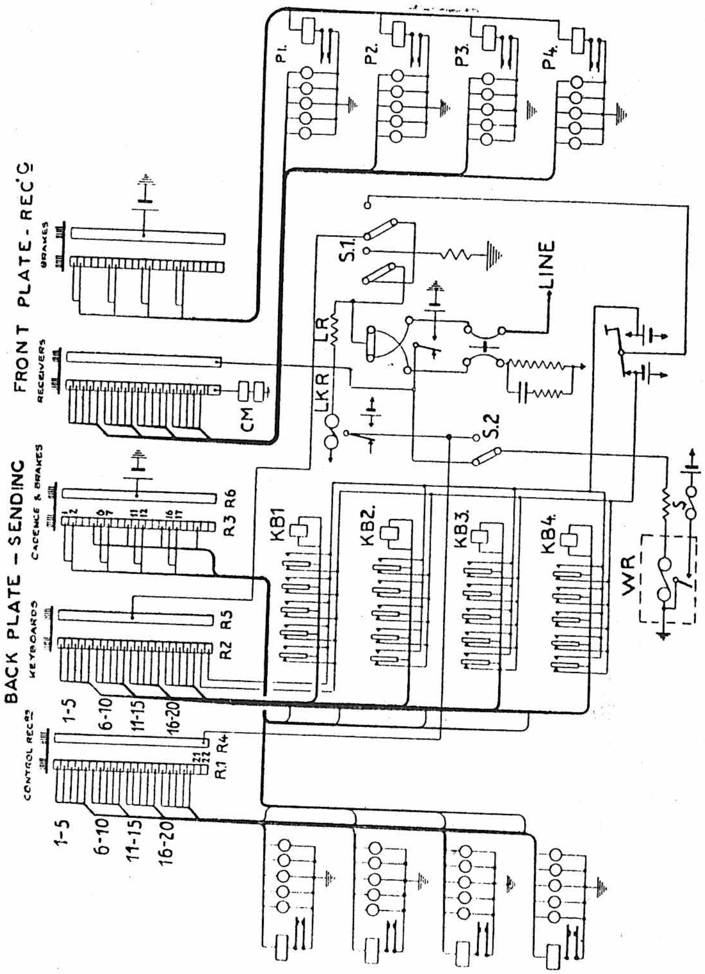

FIG. 387.

The bars and links are mounted in a frame F adapted to slide by means of rollers on supporting rods R. Two sets of teeth can come into engagement with each key lever, and their selection is

effected by the position of frame F, which is shifted to the left or the right by the letter or figure keys, which act on the two teeth shown on the upper edge of the frame.

When a key is operated it depresses a certain combination of the tee levers, and their ends act on bell cranks BC, ***withdrawing*** the distance pieces DP. A contact (not shown) is closed, and the punch hammer PH acts on those punches whose distance pieces

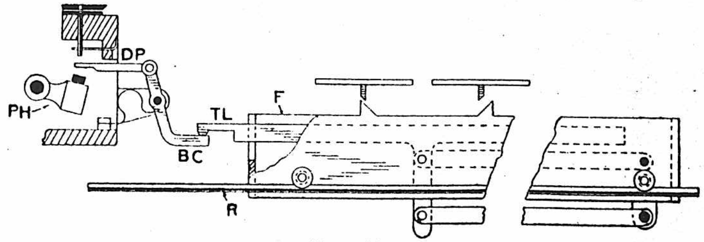

FIG. 388.

have not been withdrawn. Fig. 389 shows the two sets of teeth corresponding to the key controlling characters Q and 1. If figure 1 is to be punched, the bars will be in the " figures " position, and bars 2, 3, 4, and 5 will act to withdraw their distance pieces. Only punch No. 1 will be operated, and this corresponds to the Baudot signal for 1. If Q is to be punched, the bars will be in the letter position, and bar 2 will be operated, leaving 1, 3, 4, and 5 undisturbed. Holes 1, 3, 4, and 5 will therefore be punched in the tape, which combination corresponds to the letter signal Q in the Baudot assignment of the five-unit code.

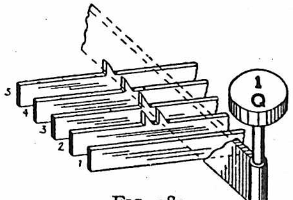

FIG. 389.

Should this perforator mechanism turn out satisfactory on trial, it solves very neatly a small problem in the modernization of the Baudot.

The modern multiplex is founded in the main on the ideas of Donald Murray. The link between the Baudot and the modern multiplex may be regarded as having been furnished by Rowland.

The Rowland multiplex embodied—

1. The duplex balance.
2. Synchronous motors for distributor drives.
3. Page printing with " page-up " means.
4. Typewriter keyboards.

Its defects were—

1. Unnecessarily long alphabet.
2. Locked keyboards and the use of a cadence signal.
3. All-electrical translation, involving a large number of contacts.
4. Power magnet control of the printer.

In spite of these defects, the Rowland system attracted a good deal of attention both in America, the country of its birth, and on the Continent. Brought out in 1899, it is no longer in use, but it served to point out to the world the great advantage of the quadruple-duplex system.

In 1903, Donald Murray described, in a confidential paper to several administrations, the "Autoplex," a multiplex system with the Murray automatic as a base. All the features which go to make up the modern multiplex were described in this paper. The autoplex had the following characteristics :—

1. Duplex balance.
2. Phonic wheel-driven distributors.
3. Idle signal to maintain synchronism when no letter signals are passing.
4. Keyboard perforators and automatic transmitters.
5. Auto stop and start transmitter device.
6. Automatic feed of cut blanks for page printer.

From 1903 to 1911 the autoplex was in the melting pot, and has undergone some modifications. As it exists to-day the Murray multiplex is adapted to work with the inventor's page printer or the Baudot printer. The printer will take cut blanks or the usual form of web. Synchronism is maintained by the Baudot epicyclic gear and correcting signals, in the standard manner, while a speed correction method has recently been invented.

The phonic wheel distributor with correcting gear, the auto transmitter, the keyboard perforator, the receiving perforator, and an earlier page printer have already been described in Chapter V., in the sections devoted to these mechanisms. Here it is only necessary to describe the latest modifications and additions to the system.

The synchronizing method preferentially adopted by Murray has been that of Baudot. The phonic-wheel drive, together with the Baudot correction, is an ideal combination, and gives synchronism as stable as a rock.

On circuits where saving of line time is of the utmost importance, then correction from the signals is essential. It is sometimes stated that correction from the signals is superior to the Baudot method when signals are distorted. It is doubtful if this statement can be proved. Signal distortion means that either extra corrections are made or corrections are missed. Additional and unnecessary correction or suppressed correction may take place within certain limits whichever form of correction is adopted, and over several revolutions tend to cancel out. If they do not do so exactly, the distributor brush arm has a small phase displacement which last for a few revolutions only. Both systems are equally susceptible, and the margin is equal also, provided only that satisfactory methods of correction from the signals are adopted.

Fig. 390 is a diagram of the Murray method of synchronism maintained by the signals. At the receiving end it will be recognized as the interfering contact method used in the Murray automatic. An idle signal is formed by reversing the transmitter lever connections to the transmitting batteries—not shown. Thus, the first quadrant sends out +ve currents to space, the other three quadrants −ve, as usual. The phasing arrangement consists of an electromagnetic key PK. When synchronizing, all the distant transmitters are stopped. The idle signal is thus sent out from the first quadrant and, at the receiving end, travels round the receiving distributor segments until the two brush arms run into phase. PK having been operated is locked up, since it closes the circuit of a battery through a holding coil and two contacts on the first printer. In addition, the holding coil has a second armature, which is now in the operated position, and short circuits the armature and contacts of the correcting relay CR. The reed is adjusted to run slightly faster than the distant reed at the correcting station. When the in-to-phase condition is set up, the setting magnets of the first printer operate their five permutation bars PB, allowing the cross-bar XB to drop and separate the two contacts included in the circuit of the phasing key holding coil. This coil releases and the distributors are now in phase. There will be some lag before XB trips, but the phase difference resulting can only amount to 1¼°, and this is corrected for during the next revolution or so.

This method abolishes the necessity for the epicyclic gear and the special correcting rings—solid and segmented—usually necessary when corrections are generated from the signals themselves. This simplification at the distributor lower the cost of construction considerably. The local connection from the line relay to the first group of setting magnets is temporarily reversed when synchronism is lost.

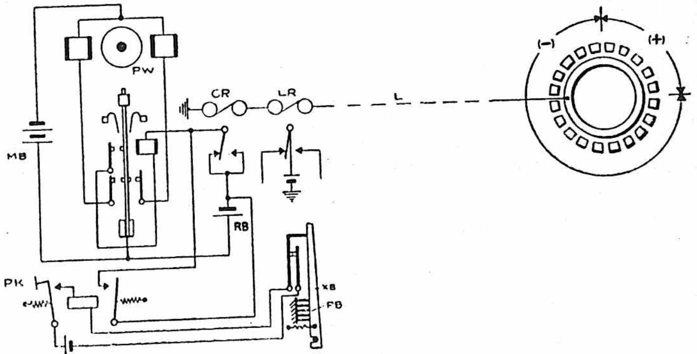

FIG. 390.

Murray has also applied the phonic wheel drive to the Baudot printer. This necessitated the design of suitable means for preserving the phase relationship between printer and distributor units. The ordinary centrifugal governor is not applicable to a drive of this character, and a step by step correcting mechanism is employed. Murray's variable coupling between the printer and phonic wheel is indicated by Fig. 391. On the shaft S is fixed a boss B, on a vertical arm of which a curved lever L is pivoted. The upper end of L carries a pawl P, which engages a series of internal teeth formed on a circular plate or ring RP. This provides the coupling means between the phonic wheel and the shaft S. When the phase relationship of printer to distributor requires alteration, a magnet—not shown—forces a pin CP into the path of the toe of L.

L turns anti-clockwise on its pivot, and in doing so draws P out and away from PR, momentarily uncoupling S and the wheel. The reset cam RSC forces CP to the normal position, freeing L, and P enters a tooth to the rear of that in which it is shown to be engaged. The printer is set to run slightly faster than the distributor brushes, as is the standard practice.

At the corrected station the distributor brush arms are continually being set back by the intermittent correcting impulses. This is equivalent to a slight advance of phase of the printers. Thus printers and distributor can be driven from the same vibrator. At the correcting station, however, the distributor speed is invariable. The phase-correcting contact must then be arranged to open momentarily once per revolution instead of closing. This is done by using a cam of type *b* in the inset, *a* being used at the corrected station. Correcting impulses are received by the printers at the correcting station until the phase is adjusted correctly, when cam *b* will open the correcting magnet circuit. The printers and distributor remain in phase because their speeds are identical, being driven by the same vibrator.

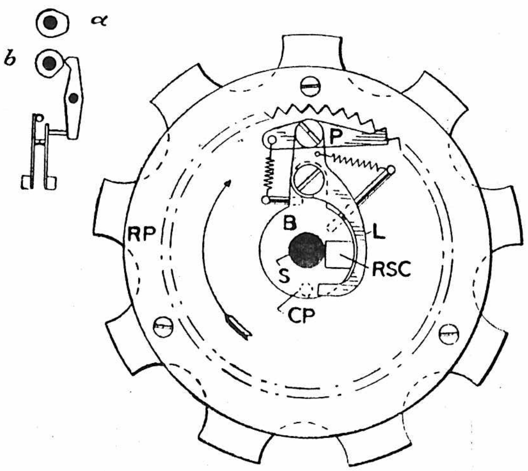

FIG. 391.

This arrangement simplifies considerably the equipment and the maintenance in operation of a Baudot circuit, and allows of change of speed when required with great facility. Standard Baudot apparatus is not adapted to readily change speed of operation. The correction of phase is 4° per tooth, too coarse to permit of its use for distributors, but the pitch of the teeth could be reduced and multiple pawls used to give the necessary fineness of step back. The arrangement can be modified to step forward, if desired. The spring between the lever L and the boss B forms a cushion, reducing the shock due to correction.

Where electrical motors of the ordinary type are used for driving continuously rotating printers, local synchronism is easily secured. Sketch *a*, Fig. 392, is a method which has been applied to the Baudot printer. Correcting conditions are set up in the standard manner, and a relay operates, disconnecting the motor battery MB, and putting a resistance R round the motor armature. The motor then runs as a generator, and its speed falls.

Sketch *b* is the means devised by Potts for the local synchronism required by the Rowland system. Each printer unit has a solid and segmented ring bridged by a brush arm rotating with the type-wheel shaft. Similar rings and brushes are provided on the distributor unit. The motor armature is across the mains through a resistance R. So long as the distributor shaft and the type-wheel shafts are in phase, R is shunted out, the segmented rings being connected segment to segment by a multiple cable. If phase differences occur, R is inserted in circuit, and the printer motor shown in the sketch slows down until printer and distributor units are once again in phase.

The Murray Multiplex Page Printer is a modification of his Automatic Page Printer, five selecting magnets being substituted for the perforated tape-selecting mechanism, and a sixth or printing trip magnet being added to control a single revolution or " start-stop " cam shaft. No synchronizing means between distributor and printer units is needed, provided that the cam shaft rotates at a speed allowing all setting and resetting cycles to be completed within the limits of one revolution of the distributor brush arms.

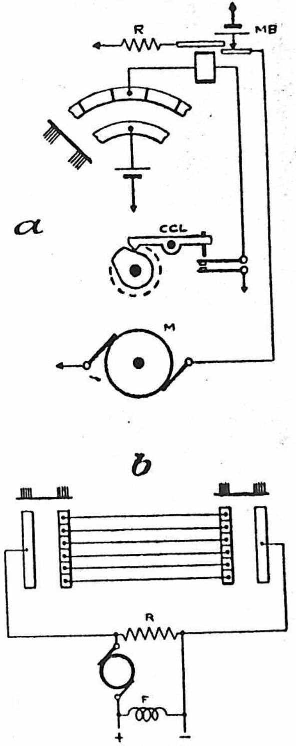

FIG. 392.

With the exception of the six magnets, the printer is entirely mechanical in its operation, and contains no electric contact. Experience has proved that printers, to be successful, must be mechanical in their operation, the operations being effected by cams on shafts driven by motors. Cams give smooth operation without shock. It is the principle of the sewing machine, and the experience of fifty years has proved that the nearer the printer approaches to sewing-machine operation the better. In the ideal printer electromagnets act as *triggers* controlling the power supplied by rotating cams. This principle finds its justification in the Hughes and Baudot printers, each with over half a century's record for reliability and low cost of maintenance.

Power magnets are noisy, and their controlling contacts give trouble. Trigger magnets require little current, and are silent in operation. Development in America is trending to the all-mechanical rather than the all-electric machine.

Telegraphic experience is also in favour of type-bar instead of type-wheel printers where speed is required. For the same reason this has also been the experience with typewriters. For speeds not exceeding 40 words a minute, type-wheel printers, such as the Hughes and Baudot, work well; but for speeds of 60–70 words per minute, the type-bar printer is more satisfactory. Type-wheel printers can, of course, be worked at higher speeds, and the Siemens and Halske printer is a case in point. Type-bar printers are more readily designed as page printers than the type-wheel pattern, and page printing is necessary to time and labour saving when speeds in excess of 40 words a minute are in question.

Experience has shown that the basket shift is lighter and quicker in action than the carriage shift usually applied to typewriters, and it is therefore desirable in a telegraph printer.

For speed and strength the paper platen sliding on a square steel spindle is the strongest and simplest arrangement.

In typewriters the letter feed of the paper carriage is an escapement or trip action, and the carriage is returned by power (hand). In printers it is desirable to reverse this, and have power letter feed with trip-line feed (carriage return).

In the Murray page printer there are four motions of the paper:—

Letter-feed.—A short horizontal motion of the paper, usually $\frac{1}{10}$ inch.

Line-feed.—A long horizontal motion of the paper, usually anything up to 72 letters, or about 7 inches.

Column-feed.—A short vertical motion of the paper, equal to the space separating two lines of print.

Page-feed.—A long vertical motion for feeding up from one sheet to another.

In the case of printers such as the Baudot, which print on a paper tape, only letter-feed mechanism has to be provided to step the paper on about $\frac{1}{10}$ inch for each letter printed. Most page printers hitherto employed have provision for letter, line, and column feed only, with the exception of the Rowland printer, which had a page-up device controlled by perforations in the blank.

In the Murray printer all four motions are provided and are completely automatic, while their operation has been speeded up in order to make page printing as economical in line and operator's time as in the case of tape printing. The Murray printer requires no more signals than a tape printer. Hitherto it has been necessary to give the time of not less than two letter signals for the "line-feed" to give the carriage time to run back to the commencement of a new line. This has usually been achieved by providing the "line" or "carriage return" signal followed by a "column" or "line-up" signal. Even this time has been found inadequate when the printer speed is raised above 40 words per minute. At 40 words per minute on a quadruple circuit the duration of a letter signal is $\frac{1}{4}$ second, and the time of two-letter signals is therefore $\frac{1}{2}$ a second at this speed. The "line-feed" of the carriage can be

secured at this speed, but at, say, 60 words a minute, there begins to be difficulty. The $\frac{1}{3}$ second then available is too short for a heavy typewriter carriage weighing from 2–3 lbs. to run back six or seven inches. Letter and column feeds can be effected in the time of one letter signal, even at 60 or more words per minute.

A further desirable feature is that the "line-feed" should automatically effect the "column feed" as, when line conditions are bad, a false signal may cause the line feed to operate. The carriage runs back, and printing then takes place on top of words already printed.

Fig. 393 is a side elevation, partly in section, of the improved Murray printer. The selecting mechanism is generally on the lines of previous printers by the same designer. The platen is mounted to slide on a rectangular bar running the whole width of the frame. This cuts down the weight of the platen and also dispenses with the need for guide rails and pulleys. The cam shaft is driven by a small electric motor of about $\frac{1}{18}$th horse-power, and the battery of cams is fixed to a sleeve surrounding this and clutched to it when the sixth or printing impulse is received. Five cams are provided—

1. The printing cam, which causes the selected type bar to print.
2. The zeroizing cam, which restores the permutation bars to zero ready for a new letter.
3. The spacing cam, which moves the paper carriage letter by letter and stores energy in a spring drum ready to return the carriage.
4. Drop cam, which actuates the universal bar allowing the cross bars to rest against the permutation bars at the moment of selection.
5. Column-feed cam, which stores up energy in the column-feed lever for the operation of the column feed at any moment required.

The printing clutch magnet CM receives regular impulses from the distributor whether a letter is set up or no. Fig. 394 shows details of the arrangement to prevent the clutch magnet operating under these circumstances, and, also, the means adopted to make the tripping arrangement very sensitive. At the left-hand end of the bars PB a slot is provided, which embraces a pin mounted in one arm of a bell-crank lever BCI. BCI is connected by a wire link or rod R to a second bell crank BC, whose lower hooked end engages with a blade or extension B of the clutch magnet armature. So long as no letter signals are set up, the armature of CM is positively restrained from motion by these means. When one or more of the bars PB are moved to the right, their slots act on the pin of BC, moving this and with it BC_2, so that the armature of CM is freed and in a condition to operate when the sixth or printing impulse is received from the distributor. The cams are clutched to the constantly rotating shaft by a claw-tooth clutch controlled by the usual type of fork F mounted rigidly on a shaft S_2. A spring S on F tends to release the clutch, but F is restrained by the following means:—The armature extension B rests against a small lug on the back of a slipping pawl SP. The front of SP is bevelled, and rests against a similarly bevelled surface on a vertical square-shaped rod, also rigidly fixed to S_2. So long as the armature extension is in the position shown in the drawing, the whole mechanism is locked, and F cannot release the clutch. If extension B is now moved clear of SP this will move in a clockwise direction, freeing

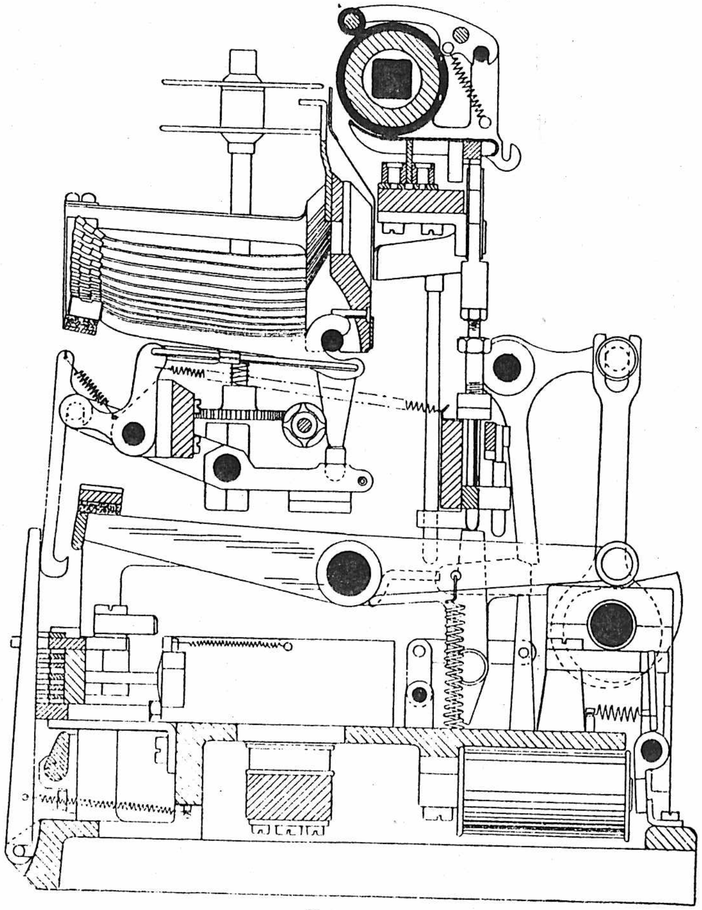

Fig. 393.

the vertical rod on S_2, and the fork F liberates the clutch. This motion takes place under the action of spring S. The bevelled surfaces of SP and the vertical rod cause the force due to S, resolved in the horizontal direction to force the SP against B, to be very slight, so that a comparatively weak force on B will move it clear

of SP. Thus, while in the normal or rest position, the locking effect is positive, although the release is readily accomplished. CM is merely a trigger magnet, while the clutching action is effected under the action of a strong spring S. The clutch is reset under power by a cam surface acting on F. The arrangement is comparable to the Hughes clutch, but is a much more elegant solution.

Fig. 395 shows the letter and line feed arrangements. The carriage is advanced step by step by a pawl FP acting on a toothed rack. The pawl is operated through the medium of a bell crank,

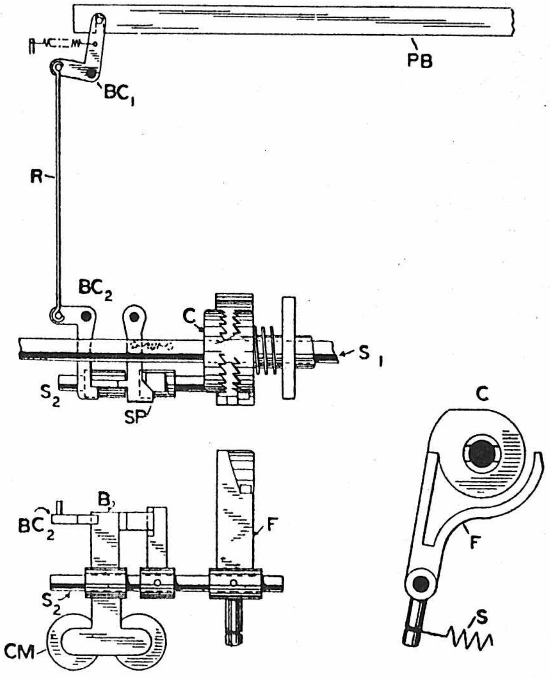

Fig. 394.

controlled by a vertical rod, and worked by a vertical rod controlled by a feed cam. The left-hand pawl HP is a retaining pawl. Both pawls have projecting pins embraced by a slot in a vertical sliding plate P. This plate is held in the vertical position shown in the drawing by a small coiled spring. When the carriage return signal is received, this plate must move down and release the holding and driving pawls with great rapidity. To this end the slipping pawl arrangement is again taken into use. A horizontal lever rests against a pin at the lower end of the vertical plate. This lever is held by a slipping pawl SP at its left-hand end, and in the positions

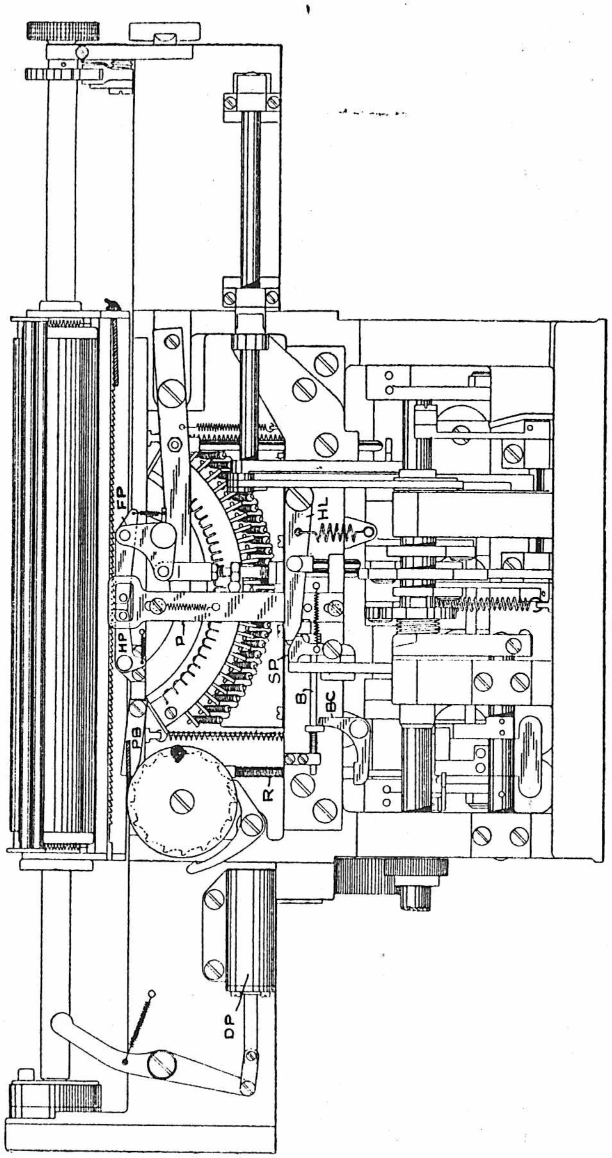

Fig. 395.

shown has extended a powerful spring connected to the frame and to a point somewhat to the left of the horizontal lever pivot. The slipping pawl is released on receipt of the line-feed signal, and HL moves downwards rapidly, engaging the pin on P and moving this and with it the pawls FP and HP clear of the toothed rack. The carriage returns under tension of the spring drum at the left of the machine. The shock at the end of the stroke is taken by a pivoted lever connected to a dashpot DP. P, and with it the two pawls, must remain clear until the carriage return is complete. To this end a bolt B enters a slot in the lower end of P, and holds the latter locked. At the end of its movement the carriage comes in contact with a bar PB, which through the medium of rod R operates a bell crank BC to unbolt P. HL is reset by power. The column feed is operated simultaneously in a similar way. It can also be operated independently of the line feed, as is required when printing an address of two or three lines.

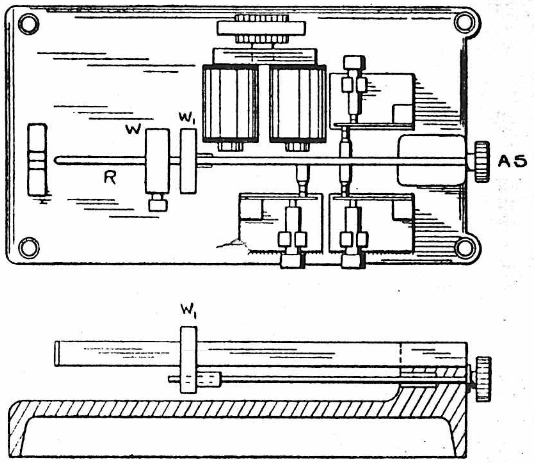

Fig. 396.

Fig. 396 is the latest form of Murray reed with Vernier adjustment of sliding weight while running.

Due to the war and its aftermath the manufacture of the Murray multiplex system has been retarded, but is now proceeding. As it is on sound fundamentals it should be successful, gradually replacing the older but, in some respects, out-of-date multiplex system at present in vogue.

Murray has borrowed good points from other systems and added many original features, the whole forming what may be termed the Modern Multiplex.

The lines of development leading up to this appear as follows:—

1. Rowland (1900). The duplex balance and page-up feed for printers.

2. Buckingham (1900). Invisible correction of errors by retraction of slip in the perforator and punching an obliterating series of dots, which, as line signals, have no effect on the distant printer.
3. Murray (1903). The Autoplex—a combination of the Murray automatic and Baudot systems, embracing auto-stop-and-start of transmitters under control of the perforator tape, phonic-wheel motors, correction from the signals with the provision of an idle signal. The page printer was adopted for taking a web or feeding incut blanks.

Later Murray developments comprised the phonic-wheel drive with epicyclic gear applied to distributors, re-perforators, tape duplicator, and transposer mechanism for converting cable code into five-unit code signals.

The Baudot system has remained practically the same as it was left by its inventor. The duplex balance and the phonic-wheel drive have been applied to it in England, and the ingenious perforator mechanism designed by Booth and Willmott is a further step in the direction of improved Baudot efficiency.

The structure erected by Murray was handed over by him to the Western Union Telegraph Company, whose engineers, in conjunction with those of the Western Electric, have carried on development on lines sufficiently characteristic to justify its designation as the American Multiplex.

Latterly development seems to have been carried on more or less independently, so that we have two American systems, the Western Union and the Western Electric.

Both systems have the following leading characteristics:—

(*a*) Phonic-wheel distributor motors controlled by massive forks.
(*b*) Single-plateau distributors with four concentric sets of rings—receiving, sending, correcting, and local.
(*c*) Keyboard perforators and tape transmitters.
(*d*) Correction obtained from the signals with consequent provision of an idle signal.
(*e*) Circuits permanently duplexed.
(*f*) Page printers of both type-wheel and type-bar patterns.
(*g*) Rotary repeaters.

Both systems are in use in America, the Western Union on its own wires, while the Western Electric system is employed on the derived channels of the American Telegraph and Telephone Company. A multiple system using the five-unit code is very much like any other similar system, and it is only details of a novel character which require treatment.

The Western Union connects up its four sets of distributor rings by means of multiple wire cables to three pin-pattern connecting plugs, as shown by Fig. 397. A panel is furnished to take the plugs, of the type diagrammatically indicated in Fig. 398, and this arrangement allows of the distributor being readily disconnected and removed from the circuit without need for disturbing the permanent wiring. The panel further allows of transmission being retarded and advanced by merely withdrawing the plug and rotating it in the necessary direction. The Western Union practice is to adjust for orientation by advancing transmission, any adjustment

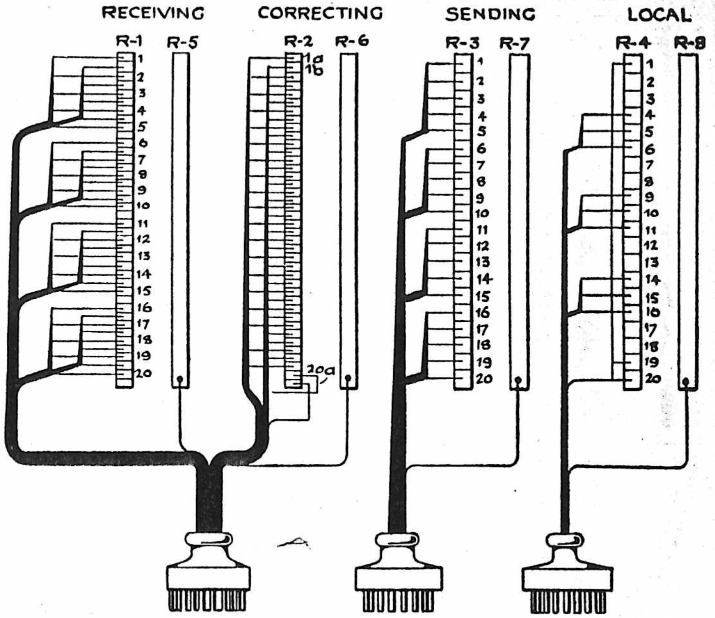

FIG. 397.

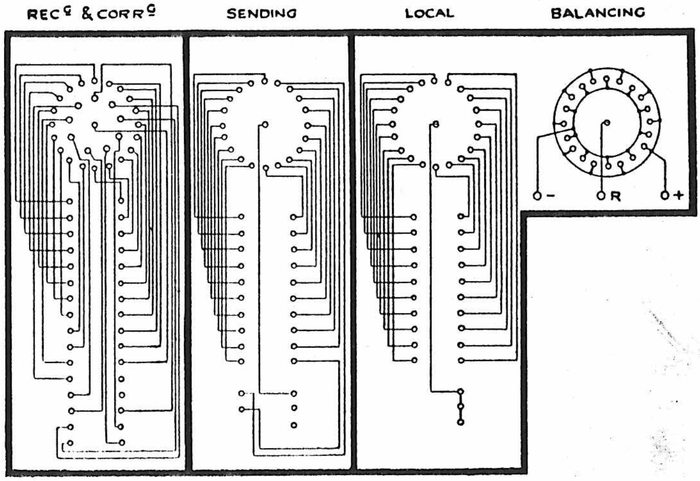

FIG. 398.

SPEEDING UP THE TELEGRAPHS: A FORECAST OF THE NEW TELEGRAPHY.

By DONALD MURRAY, M.A., Member.

(*Paper first received* 15*th September, and in final form* 29*th October; read before* THE INSTITUTION 18*th December*, 1924.)

SUMMARY.

This paper, which is mainly a forecast of the probable form that the telegraph service will take in the course of the next 25 years—a form that is described as the "new telegraphy"—refers to the world-wide complaints about the unsatisfactory condition of the telegraph service and the need for improving it and speeding it up until it takes its proper place alongside the telephone.

It is agreed that these complaints are well founded, and the telegraph service is described as being dear, slow and inaccessible. Speeding up the telegraphs and bringing them into closer touch with the industrial and financial life of the world is put forward as a necessity of the future. We must type as well as talk. We must "teletype" as well as "teletalk."

It is pointed out that the telegraph has many important advantages over the telephone, especially for communicating over distances of more than 50 miles, and the present ailment of the telegraph is diagnosed as excessive circuit facilities and defective terminal facilities. That is to say, there are more circuits than are required for the traffic at present available, and not sufficient telegraph machinery, and the telegraph equipment is not arranged, like the telephone, so as to be linked up closely with the business life of the community. The telegraph is not, but should be, at every business-man's elbow, like the telephone.

The remedy is the creation of printing telegraph or, more briefly, teletype exchanges, giving telegraph facilities similar to the telephone facilities we now enjoy. This will evidently be the result of certain developments now taking place in America, where both the Western Union and the Bell Telephone Companies are about to offer telegraph typewriter service to business men, that is to say to subscribers. If this proves commercially profitable, it will inevitably lead to the establishment of teletype exchanges in all the American cities, and they will be linked up by trunk or long-distance telegraph lines. This will put business men all over the United States directly in touch with each other by printing telegraphy. In this way the new telegraphy will be born.

The paper foretells that, in the course of years, this new development will have a revolutionary effect on telegraph offices, which will become automatic switching exchanges, very like an automatic telephone exchange; and the telegraph operators, like the telephone girls, are doomed to disappear, and their places will be taken by a few telegraph engineers and mechanics wandering about in the deserted telegraph operating-rooms, looking after the telegraph switching apparatus.

Examples are given of the advantages that this new telegraphy will confer on the business community.

The machine that has made this new telegraphy possible is the start-stop telegraph printer—provided with a typewriter keyboard and requiring only momentary synchronism. It can therefore be readily switched from one circuit to another. It can work at from 40 to 80 words a minute over any distance from 100 feet to 5 000 miles, and any girl typist can use it. This is the business-man's printing telegraph—the Ford car of telegraphy.

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Part 1.

THE WORLD'S UNSATISFACTORY TELEGRAPH SERVICE.

(1) *The modern demand for speed, and why.*—A paragraph in the newspapers, entitled "Speeding up the Telegraphs," has supplied the title and inspiration for this paper. The paragraph, which has already been widely quoted and commented upon, appeared in the following form in the London *Daily News* of the 26th February, 1924:—

> "SPEEDING UP THE TELEGRAPHS.—RIVALRY OF WIRELESS AND AIR MAILS.
>
> "PARIS, Monday.
>
> "It is announced here that the International Telegraph Union at Berne is proposing a world inquiry into the growing neglect of the telegraph in internal and international communications.

The Journal of the Institution of Electrical Engineers

"In some countries, such as the United States and Scandinavia, the telegraph now contributes hardly more than 1 per cent of the total number of electric communications, and in France, where lack of enterprise still leaves over 40 per cent of the 36 000 communes unserved by the telephone, the proportion is only about 10 per cent.

"The air-mail is mentioned as becoming a powerful rival to the telegraph wire. A letter posted in Paris at 7.50 p.m. is now delivered at Casablanca, in Morocco, on the following morning but one, which is not always, but is sometimes, as rapid as the telegraph, and has other advantages.

"In a single month last year 200 000 communications were sent by this air route. The use of wireless telegraphy is growing very rapidly. The great station near Bordeaux sends messages as far as Saigon. Saint Assise serves America, and Lyons, Moscow and Central Europe.

"It is suggested here that if the plant and cables of the old system representing hundreds of millions are not gradually to be scrapped, tariffs will have to be reduced, and the service everywhere speeded up. In France it still often takes five hours to telegraph between Paris and Nice, and this is only an instance of the wide margin left for reform."

The same paper published another significant paragraph on the 18th June, 1924, as follows:—

"TELEPHONING EXPRESS.—QUICKER METHOD OF TRANSMITTING PHONOGRAMS.

"The telephoning of express messages is to be expedited.

"Hitherto a telephone subscriber has telephoned his message to the nearest exchange, whence it has been sent to the next exchange, and so on, necessitating its being re-written perhaps three or four times.

"Under the new system a subscriber is to be plugged through to the nearest central transmitting office. He will be charged only the local fee. A subscriber, for example, who wishes to dictate an express message from Stockport will be put through to Manchester, and one who speaks from (say) Norwood will be put straight through to the Central Telegraph Office, St. Martin's-le-Grand.

"The new scheme is criticized by the Union of Post Office Workers. Mr. Fred Riley, the assistant secretary, said yesterday:

"'The union claims that phonogram work is strictly telegraph work, requiring a full knowledge of telegraphic rules and regulations.

"'In the transfer of work from telegraphists to telephonists the Post Office is guilty of down grading of work contrary to the trade union practice. The union agrees to such transfer only on the condition that telegraph rates are paid.'

"Mr. Riley added that errors in telegraphy were negligible compared with those in telephony. He said the scheme appeared to be a great menace to the staff, and had no advantages for the public."

As these two paragraphs deal with a subject of the greatest importance to the industrial and business world, namely, quick and cheap intercommunication, it seems to be desirable that a clear, hill-top view of the facts and probable and possible developments of telegraphy, as they appear to one who has devoted many years to the subject, should be put on record in circumstances which may lead to wide public discussion. By such discussion the business world will become conscious of the possibilities, and a very desirable stimulus will be given to the growth of the great telegraphic facilities that will be available to us in the course of the next 25 years. I have therefore avoided technicalities, and comcmuniation engineers will find nothing new in this paper, except the unusually extensive landscape.

If we had no telephones, the world would be very proud of its marvellous telegraph service; but the colossal growth of the telephones, and the wonderfully quick and cheap service that they render, have made people dissatisfied with the results at present obtained from the telegraphs.

There have been articles innumerable in the technical and lay Press about the unsatisfactory condition of the telegraph service and the need for cheapening and speeding up the telegraphs to save them from extinction, and all sorts of weird remedies have been proposed. We have been told that the world's telegraphs are in the melting-pot, and that they are liable to be swept away by the telephone and wireless and by the air-mails, and nobody seems to know what to do to remedy this state of affairs. The ideologues and word-merchants suggest that the telegraphs need to be "reorganized," and practical telegraph men recommend "advertising the telegraphs" and "cultivating the telegraph habit." Advertising is good as far as it goes, and the Western Union Telegraph Company finds that this policy pays, and a really remarkable telegraph advertising campaign is carried on in America.

The company has been good enough to send me a collection of its advertising leaflets. These are amazingly clever, and cover all phases of life from the use of telegrams to collect overdue accounts, to sample telegrams to radio artists with the advice "Applaud by Telegraph." Amongst scores of others, there is a card giving the average cost of letters at 52 cents and telegrams at 60 cents. In Great Britain the corresponding cost of an average letter is probably about 1s. and a telegram about 1s. 3d. The argument is that the saving of time at the cost of a few extra cents is extremely profitable. Through all the advertisements runs the refrain "Don't write—Telegraph!"

Note these last words attacking the mail-bags.

Practical telegraph men realize that telegraph traffic is not likely to grow faster than the slow annual increment due to increase of population, if the present lines of development are adhered to, and they know that there are only two other directions from which increased traffic can be expected. The telegraphs have suffered from the pressure of the telephones on one side and the Post Office on the other, and the obvious remedy is for the telegraph men to attack the telephones and make war on the mail-bags. Hence the advice in the advertisement, "Don't write—Telegraph." There are also night-letter telegrams and various other devices to divert correspondence to the telegraph wires, especially during the ebb-tide when the volume of telegraphic traffic is low.

Clearly this advertising shows that the Western Union telegraph plant is not being used up to its capacity; and that is the position with all telegraph administrations. There is a shortage of telegrams and there is no shortage of telephone messages. Unfortunately it is not much use to advertise the telegraph service while it is dear, slow and inaccessible. When the telegraphs become as cheap, quick and accessible the telephones, the telegraphs will not have so much need to advertise.

The chief complaint is about the slowness of the telegraph service, and the complaint is world-wide. For instance, a paragraph in the *Telegraph and Telephone Journal* for June 1924 says :—

"The annual report of the P.M.G. of Australia shows a loss on the telegraph branch of some £78 000 on the year 1922-23. Out there, as here, the speedier delivery of telegrams is a problem not yet solved. It is, however, noted that a distinct promise of an acceleration in that direction has been made."

This demand for greater speed has a deep economic significance, and it may be pointed out, in passing, that the idea of doing things quickly is modern, and it exists only in highly industrialized communities. Some years before the war when I was in Moscow, I was told that "Time is not money in Russia." I was also told that "The Lord God has plenty of time." However, the Russians are adopting modern habits, and all over the world " mañana " is giving way to " pronto."

The explanation of this modern haste lies in the fact that a profit of a shilling an hour is better than a profit of a shilling a day. In other words, the faster one does business the more business one will be able to do and the greater will be one's annual dividend. Every business man knows that, and every business man knows how profitable it is to use the telegraph and telephone. The telephone saves a colossal amount of time, and is one of the main factors in the vast production of modern wealth. The telegraph, the senior service, helps, but not to anything like the extent that it ought to do.

Examples of this speeding up of business may be found throughout every community, and an amusing instance is the speeding up of moving pictures so as to get more programmes through and to get more audiences squeezed into one day. This gives a bigger turnover in audiences and a bigger profit on the day.

In the language of political economy an essential part of the process of division of labour is exchange of the goods produced, and anything that increases the velocity of that exchange facilitates the division of labour which is one of the two great factors in the production of our modern wealth.

In this speeding up of the turn-over, the telephone and telegraph play a very large part, but the telegraph, for various reasons, has lagged behind. Recent developments, however, with which this paper deals, indicate a great extension of the telegraph service. The business man wants to speed up business, and for that purpose he needs a vastly improved telegraph service, and he is going to get it. He will have to pay for it ; but the profit is so great that he will pay gladly when he gets accustomed to the price. By business men I mean not only individuals but organizations, merchants, banks, stockbrokers, factories, railways, farmers—in fact the whole financial and industrial community.

(2) *Telephone versus telegraph.*—In order to get an idea of the possibilities of telegraphy, it has to be remembered that there are only two practicable methods of communication—by the ear, and by the eye. We can talk and we can write ; we can telephone and we can telegraph. At present the telephone has no effective rival, it has interwoven itself into the industrial life of the world to an extraordinary degree, and to a substantial extent it is doing work that the telegraph could do better, especially over considerable distances ; but for a variety of reasons the telegraph has not been able to stand up against the competition of the telephone, and the result is that the telegraph has been cramped and stunted between the competition of the telephone service and the postal service.

This stunted growth of the telegraph is economically unsound. It is not good for the community, and it is also certainly not permanent. It has been due essentially to the imperfect development of the telegraph plant. It is true that the telephone also is only now reaching the machine stage ; but the telephone has always had the great advantage that the transmitting and receiving mechanisms, the human tongue and the human ear, cost nothing, are ready made, and are highly perfected and capable of any speed up to about 150 words a minute. All the telephone engineer had to do was to provide wires and suitable switching arrangements and extremely simple transformation devices to catch and reproduce the human voice. The telegraph engineers, on the other hand, were heavily handicapped by the burden of having to make satisfactory machinery that would typewrite at a distance. This proved to be a very difficult task, and although printing telegraphs have been in existence for 50 years, the business-man's printing-telegraph has only been perfected during the last few years. The reasons will be given later. This is the one and only important reason for the backward condition of the telegraph compared with the telephone. We realize this fact at once when we consider that if we could all speak the Morse Code language the telegraph would not be the Cinderella of communication. It is only now that this handicap is beginning to be removed, and speeding up the telegraphs, or, more strictly, speeding up the transit of telegrams, has begun. This perfecting of the telegraph machinery will be dealt with presently.

It is, of course, hopelessly idealistic to suppose that, for moderate distances, the telegraph can ever be as quick and as intimately connected with the life of the community as the telephone ; but we are safe in assuming that in 15 or 20 years business men will have at their disposal a telegraph service, by wire and wireless, far quicker and more accessible than at present, and progressively cheaper than the telephone for distances exceeding, say, 50 miles. If business men could telegraph over distances exceeding 50 miles more easily and quickly and cheaply than they can telephone (and that will be the case by and by) what would be the result ? Clearly the new facilities would create much new traffic ; but, in addition, many messages now going by telephone would go by telegraph, and also a great many letters that now go by mail would go by wire. The telephone has great advantages over the telegraph, but a perfected telegraph network would have other great compensating advantages over the telephone. We must type as well as talk; we must teletype as well as teletalk. A telephone message is a voice, and nothing more—a sound leaving no record. Nothing is more evanescent. There are sound-recording machines, but the sounds are still sounds, and there is no conceivable mechanism, outside of the human brain, that will translate a sound-message into a sight-message. It is sight-records and not sound-records that we need for business purposes, because they occupy so little space compared with any sound-record and are so much cheaper. They can also be glanced over so quickly and read at the rate of 300 words a minute. Business demands speed, and we must type and teletype when records are needed. Civilization began when we started to write, and modern civilization began when we started to type. Now we are starting to type by telegraph on a large scale by modern mechanisms.

(3) *Weaknesses of the telephone.*—Not only is a telephone message merely a passing sound, but also in order to gain its undoubted advantages it has to be exceedingly wasteful of signalling material. This is readily seen when we examine the vibrations or signals that have to be transmitted over *two* telephone wires for a single word, say " Paris," compared with the vibrations or signals required to transmit over *one* telegraph wire the same word in the five-unit alphabet.

In Fig. 1, A is an oscillograph record of the electric oscillations in a telephone circuit when the word ' Paris " is spoken rapidly into a telephone receiver. I am indebted to the Post Office Research Station at Dollis Hill for this extremely instructive oscillograph.

B (Fig. 1) is a timing record with a frequency of 1 000 cycles or vibrations per second. On B therefore 100 waves mark off $\frac{1}{10}$ second, and it will be seen that the word " Paris " spoken rapidly into the telephone occupied about $\frac{1}{3}$ second, or 1/18th of a second per letter. (Five letters and the space after the word, or, in all, six letters, are taken as the standard word.) Dividing 60 seconds by 1/18 we get 1 080 letters or 180 words a minute. The number of waves or cycles required to transmit the word " Paris " telephonically was 365.

Immediately below, in C (Fig. 1), there has been marked off the number of cycles in B required to transmit the word " Paris " in a telegraph wire by the five-unit alphabet. As start-stop printers use what is really a seven-unit alphabet, we multiply the six letters of the standard word by seven, thus getting 42 units, or 21 waves required to transmit the word " Paris " telegraphically by a start-stop printer, compared with 365 waves required for the telephonic transmission of the same word. It is to be noted that 365 is an average figure, including the low as well as the high frequencies. For a real comparison with the telegraph we have to take the highest frequency that must be used to transmit clear speech, and not the average. If we take this average of 365 cycles for the five letters of the word " Paris," we get 75 cycles per letter, compared with $3\frac{1}{2}$ cycles for the telegraph, a ratio of 21 to 1 in favour of the telegraph.

In D (Fig. 1), I have given the word " Paris " in the seven-unit alphabet transmitted in the same time as the telephone word. This again illustrates the advantage of the telegraph in the fewness and slowness of its signals compared with the telephone. Obviously this handicap in signalling places the telephone at an extreme disadvantage compared with the telegraph so far as the line is concerned, and the longer the line

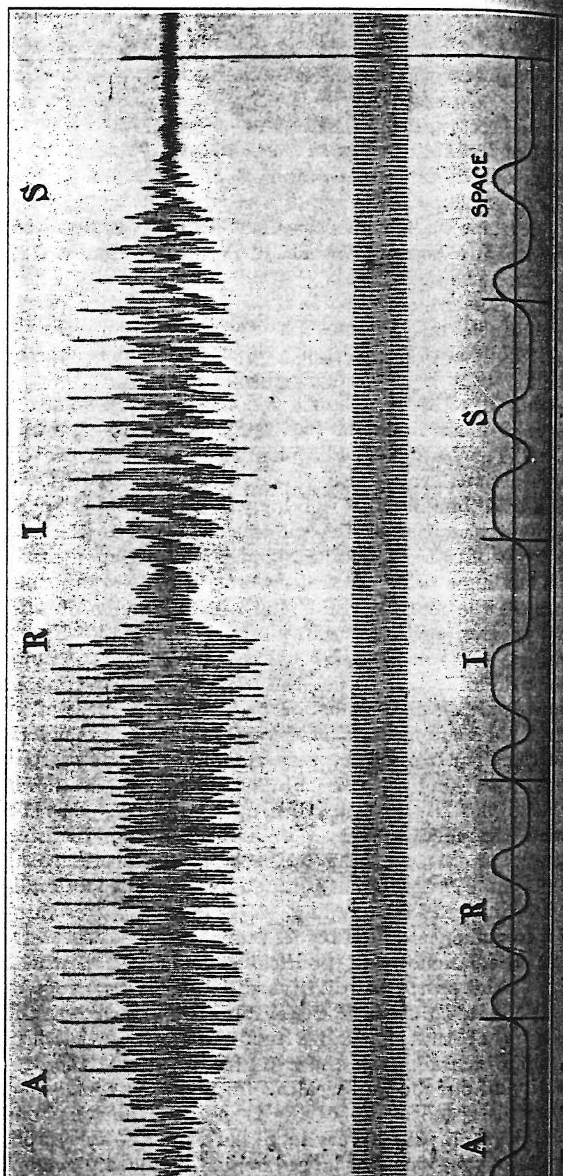

FIG. 1.—Comparative diagram of telephone word and telegraph word "Paris."

[illegible]

Fig. 1.—Comparative diagram of telephone word and telegraph word "Paris."

the greater the handicap. Wonderful devices are used by telephone engineers to overcome this drawback; but the same devices can be used in telegraphy, and nothing can remove the handicap.

Another way of comparing the telephone and telegraph, so far as line signals are concerned, is to use the following information, for which I am also indebted to Dollis Hill:—

"The question of the lowest and highest frequency necessary for good speech is very largely dependent upon the quality of speech required. The following figures show the order of values:—

(1) Complete unintelligibility occurs with the elimination of all frequencies above 500 cycles or below 2 000 cycles per second.

(2) Experts can carry on a conversation with all frequencies either above or below 1 000 cycles eliminated, but the quality is poor.

(3) The most important range is from about 600 to 1 200 cycles.

(4) For good quality commercial speech it would probably be advisable to cater for all frequencies between 200 cycles and 2 000 or 2 500 cycles per second, while for perfect reproduction and for music 100 to 5 000 cycles at least are necessary. For the generality of cases 800 is an accepted frequency which can be used to represent speech frequency."

As the weakest link in the chain is the determining factor, we have to take the lowest limit of the highest frequency required for clear speech; that is 2 000 to 2 500 cycles, or, say, 2 400 cycles per second. Multiplying this by 60 gives us 144 000 waves per minute. Dividing this by the 3½ waves per letter used by start-stop printers, we get 41 140 letters, or 6 850 words per minute if we used the same frequency for telegraph work.

The telephone will not give more than 180 words a minute; and actually the average rate is probably not in excess of 120 words a minute. A skilful public speaker does not exceed about 120 words a minute if he is wise, and the rate of the average speaker is about 150 words a minute. It is possible to read silently at the rate of about 300 words a minute. Normal conversation is extremely rapid, and runs up to about 200 words a minute; but such a high speed is impossible on the telephone, because a little more effort is required to speak into the telephone and there is also more effort to hear what is said. Taking the telephone speed, however, at the very favourable figure of 150 words per minute, we find, on dividing 6 850 words per minute by 150, that the telegraph is 45 times more efficient than the telephone so far as the utilization of the line signals is concerned. Even if we come down to what Dollis Hill calls poor-quality speech, namely the 1 000-cycle limit, the telegraph is still 19 times more efficient than the telephone so far as the line is concerned.

This calculation can be put in another form as follows: Taking the standard word as composed of six letters (including the space), 150 words a minute is 15 letters per second. Taking our upper limit of frequency for clear speech over the telephone, namely, 2 400 cycles per second, and dividing by 15, we get 160 cycles per letter for the telephonic transmission of intelligence. In telegraphy the rate per letter, using the five-unit alphabet, is 2½ cycles, or 3½ for start-stop printers. Dividing 160 by 2½ we get a ratio of efficiency of 64 to 1, or with 3½ cycles, 45 to 1, as before.

This takes into account only the handicap of frequency. The telephone, however, also depends largely on varying amplitude of vibration. There are hundreds of different amplitudes with the telephone and only one amplitude with the telegraph. Hence, if we take amplitude as well as frequency into consideration, we shall probably be within the mark in saying that there is a handicap of 100 to 1 on the telephone compared with the telegraph, so far as the line is concerned.

I have gone at length into this comparison, because the whole future of the new telegraphy depends upon it. The figures quoted make it clear why the telegraph can be so much cheaper than the telephone when distance becomes an important factor.

For the information of many non-technical people who, I hope, will read this paper, I may mention that there is a practical limit to the rate of electrical vibration and also to the variation of amplitude that can be transmitted over any given size and length of wire, and the longer the wire the lower the limit. It is this fact that imposes a handicap of 40 or 50 to 1, and even 100 to 1 on the telephone compared with the telegraph.

With the telephone the risk of error is great, because the electric currents representing the voice not only have a very high periodicity but also are extremely feeble. They are likewise very delicate, because varying amplitude is an important factor. To shut out disturbances which would ruin these extremely delicate telephone vibrations, it is necessary to use a loop made up of two costly telephone wires for one message. Also it is only possible to speak on the telephone simplex; that is to say, a man cannot talk and listen to the telephone at the same time. The telegraph can do so. It can work duplex, and the "single-operator duplex" is going to be important by and by. Consequently, the limit of speed on the two costly telephone wires is 150 words a minute, that is to say, 75 words a minute on one wire.

It is true that by various ingenious devices several telephone circuits can be so linked up as to give additional telephone circuits, and there is also the "carrier current" system. But we can apply to telegraphy all these expedients of telephony, including Pupin coils and valves and tone frequencies, the result being many times greater carrying capacity with telegraphy than is now obtained. The position, therefore, is that for working at 150 words a minute by telephone we need two costly telephone wires, that is to say, a telephone loop, or 75 words a minute on one good wire. The telegraph, on the other hand, only requires one wire at about half the cost of the telephone wire, and will give 240 words a minute each way simultaneously, or 480 words a minute in all, on the one cheap wire. This is from 12 to 16 times more than the telephone can do, and the consequence is either a correspondingly greater carrying capacity for the wire, or a correspondingly greater distance covered. It means that for any considerable distance, and particularly for long distances, the telegraph is far cheaper than the telephone. It is for this reason chiefly that the stunted growth of the telegraph is economically unsound. There is also the great advantage with the telegraph process of being able to store up telegrams in order to send them at opportune times.

There are other serious handicaps to the telephone. For instance, it is impossible to talk in the absence of one of the parties to the conversation, and it is often a waste of time to have to receive a telephone message personally. In this respect telegraph printers offer the notable advantage of recording messages in the absence of the addressee, thus avoiding interruption of work and delay, the messages being stored automatically until an opportune moment arrives. Writing or typing a message saves much time. A business man in the morning finds a pile of letters opened by his secretary ready for him to read and reply to by the aid of his stenographer. In an hour he can dispose of matters by letter that would take him all day, even if possible at all, by telephone.

A letter is a great time-saver. We can dictate a letter when we please and when we have time, and the dictation can be interrupted by more urgent work and no harm is done. We have time to think when dictating a letter. Also the recipient is saved a great deal of time. He can glance through a dozen letters in the time that he would receive one corresponding message by telephone, and he can deal with letters at any time and in any way he pleases. He also has time to think about them and hunt up information. Under suitable conditions many of such letters could be sent by telegraph with great saving of time and without diminishing the foregoing advantages. It would not be practicable to send such letters by telephone. It would be too costly, except over short distances for which the post is better, there would be no typed record, and the possibilities of mistake by telephone are too great for commercial security.

The telephone, in its own way, is also a great time-saver, especially in getting an answer back forthwith; but let me repeat: We must type as well as talk; we must teletype as well as teletalk, and the reasonably perfect telegraph service, as good as the telephone, such as we expect to see in 15 or 20 years, will certainly do a lot of work well, now done by the telephone badly.

(4) *Other competitors of the telegraph.*—In the first paragraph quoted at the beginning of this paper reference was made to the competition that the telegraphs have to suffer from wireless and the air mail. This is a mistake. It is true that wireless offers great possibilities for rapid communication. Wireless, however, considered from the point of view of this paper, has only indirect connection with telephone and telegraph work. It is really a remarkable substitute for telegraph and telephone wires and submarine cables, and it multiplies the facilities for the use of the telegraph and telephone. A telegram is a telegram whether it is sent by wire or wireless, and wireless need not, therefore, be further considered in this paper.

So far as the air-mail service is concerned, it cannot compete with the telegraph except for handling documents. In this particular respect, aeroplanes may help to empty the ordinary mail-bags, but the risk of loss of valuable documents is too great in the case of aeroplanes; and for urgent communications such as are suitable for telegraphy the aeroplane has no chance in competition with the telegraph. Take London and Paris; under the most favourable conditions it takes about 4 hours for a letter posted in London to reach Paris by air mail.

The actual time of transit at the present day is as follows:—

Charing Cross to Croydon Aerodrome, about 40 minutes; Croydon Aerodrome to Paris Aerodrome, about 2½ hours; Paris Aerodrome to Paris, about 30 minutes; Total time of transit, about 3 hours 40 minutes.

This takes no account of the time required to make up the mail in London and to deliver the letter in Paris. Taking the total time at 4 hours, only 20 minutes would be allowed for posting and delivery. The speed of commercial aeroplanes is only about 80 to 90 miles an hour, and even this speed is greatly affected by the wind. If we reckon 100 miles an hour for the aeroplane, it would take more than an hour to post, transport and deliver a letter between London and Birmingham. With the new telegraphy between London and Birmingham, a message would go through from typist to reader in about 2 minutes, and a reply would go back within another 2 minutes if the subject-matter permitted an immediate answer. A properly developed system of telegraphy would deliver a long telegram from a correspondent in London to a correspondent in Paris within 10 minutes. The new telegraphy has nothing to fear from the air mail.

So far as the postal service is concerned, the fundamental advantage is the extremely cheap rate of postage, 1½d. per letter, and the letter may contain several thousand words if closely typed on thin paper. One reason for this cheapness is that the paper and envelope of an ordinary letter are not supplied by the Post Office, and the labour of writing or typing the letter is not done by the Post Office. There is distinct material- and labour-saving in this, or, more strictly, a transfer of labour and cost of material from the Post Office to the individual or firm, just as automatic telephones transfer the labour of making a connection from the telephone girl to the subscriber. It will be seen that the new development of the telegraphs foreshadowed in this paper will effect the same transfer of labour from the telegraph administration to the individual or firm. Another advantage of the postal service is that cheques and other documents that cannot be telegraphed or telephoned can be sent easily and cheaply by post. The great handicap of the mail, and one main reason for its cheapness, is its extreme slowness, at the outside 60 miles an hour on land, and by sea not more than about 25 miles an hour, and even by aeroplane not more than 120 miles an hour. For short distances within city limits this drawback is trifling and, on account of the extreme cheapness of the service, all communications that can stand a few hours' delay will always go by post within city limits. The greater the distance, however, the greater the advantage of the telegraph for messages requiring speedy delivery.

There is appropriate work for each of the three services of communication, the post, the telegraph and the telephone. There are certain things that each can do better than the other two, and during the next quarter of a century the telegraph will recover ground which, through transient causes, has been lost to the telephone and postal service.

(5) *The defects of the telegraph service.*—The defects of the telegraph service are not appreciable to the average man, and it is not until we begin to consider how the telegraph service might be improved and how inferior it is compared with the telephone, that we realize that it is slow, costly and inaccessible. For moderate distances the telephone is as cheap as the letter post, and we can get through to anyone we want in a minute or two. The telephone is quick, cheap and very accessible. At my desk I am in close, quick and cheap touch with London, thanks to the telephone, and I ought to be in similar touch with the world by telegraph, but I am not. The telegraph does not possess the close linkage enjoyed by the telephone with the business world. It is true that I can telephone a telegram to the Central Telegraph Office, and so speed up the telegram to some extent; but at the Central Telegraph Office my telegram or cablegram has to do a lot of "circulating" before it reaches the point of departure over the telegraph line or the ocean cable, and at the other end it has to do more "circulating" before reaching its destination. The telephone-telegram, or, as the British Post Office calls it, the "phonogram" service is a valuable facility for an occasional telegram or cablegram; but it is a nuisance if one has to send many telegrams, and it is far from accurate, unless the message is repeated and the words spelled out analogically, "T" for Tommy, "H" for Harry, and "E" for Edward. That makes it irritatingly slow when sending many telegrams. The telegraph, with proper machinery, could beat the phonogram with ease when numbers of messages are concerned. Obviously, compared with the telephone, the telegraph is at present very inaccessible, and it is nothing like so quick. It is cheaper for long distances, but dearer for short.

The defects of the telegraph are clearly not due to lack of circuit facilities. There are enough telegraph circuits to carry more than double the present available traffic. There are, indeed, excessive circuit facilities, as will be explained presently. It will be found upon investigation that the shortcomings of the telegraph service are due almost entirely to defective terminal facilities. The patient's condition may be diagnosed as "excessive circuit facilities and defective terminal facilities." Fortunately the prognosis is favourable. The terminal facilities are going to be greatly improved in the course of the next 25 years, and the resulting increase of telegraph traffic will absorb the excess of circuit facilities.

Looking at the telegraph situation to-day, we see good organization and capable management; but we also see excessive development of circuit facilities, due to competition and to international jealousies and to unforeseen technical improvements. Side by side with the complaints about the unsatisfactory condition of the telegraph service, there are many reports in the Press about more telegraph cables to be laid. New and wonderful "permalloy" cables are being made to give 300 words a minute instead of 30 across the Atlantic; the nations are insisting upon having their own cable and wireless services; and investors are beginning to wonder where the traffic is to come from to pay interest on the heavy capital expenditure. Another important element in the creation of excessive circuit facilities is the widespread provision of telephone trunk lines, each composed of two wires; and the ease and cheapness with which telegraph circuits can be created by superposition on these telephone trunk lines adds to the present superfluity of telegraph circuits. Telegraph-circuit facilities are also increasing to an extraordinary extent in consequence of technical developments in radio-telegraphy, which have shed new light on the solution of old telegraph problems, and have shown how to split up one wire into 10 or more channels. There are phantom circuits, superposed circuits, carrier-current circuits or wired-wireless telegraphy giving wonderfully increased carrying capacity; and quite distinct from this are tone-selective methods or harmonic telegraphs, which appear at last to be getting on to a practical basis. Then, in addition, we have wireless telegraphy constantly improving its methods and range and practical carrying capacity. Some time ago that wise old institution, the British Post Office, seeing how matters were developing, altered the wording of its contracts for leasing wires by inserting the words "channel of communication" instead of "wire," so as to reap the benefit of the rental of, say, 10 or more channels into which one wire may now be split up. It is probably not an exaggeration to say that the present telegraph plant of the world, wire and wireless, can handle twice the present volume of traffic; and technical developments, now past the experimental stage, can multiply the present telegram-carrying capacity by 10. In other words, the telegraph circuit facilities of the world are, on the average, at least twice as great as the available traffic, and these facilities, by the expenditure of 15 to 20 millions sterling, can be increased sufficiently to handle from 15 to 20 times the present traffic.

But these wonderful facilities suffer from a grave defect. They do not link up closely with the business man. The telephone does, and the telegraph does not. The telegraph has to get the assistance of the telephone to complete the linkage. That is quite satisfactory for the occasional telegram and for the private and domestic message; but big users of the telegraph require something better. They need a telegraph linkage that will put them directly in touch with their correspondents, just as the telephone does. The really important part of the telegraph traffic is that devoted to business, and this paper is concerned chiefly with business telegraphy.

There is another important point to be borne in mind when considering future telegraph developments, and that is the underground cable. The world cannot afford to have communication between its great cities interrupted by the weather. Within comparatively few years all big cities will be connected by underground cables both for telegraphs and telephones, and this will alter the aspect of circuit facilities. Underground cables give conditions which are so stable and so free from disturbance when loop circuits are used, that circuit facilities depending on the use of feeble high-frequency vibrations will become much more usable than they are at present. Aerial lines have to be employed as loop circuits like telephone lines to get satisfactory results by these new high-frequency methods, and it is a very interesting question whether such high-frequency aerial-loop circuits can show any commercial advantage over the ordinary multiplex. On underground cables, however, the conditions are very favourable, and attention is being directed to the question of using carrier-current methods, or, more strictly speaking, voice-frequency or tone-selective telegraphy for underground wires. American engineers—including particularly those of the Western Electric Co. and the American Telegraph and Telephone Co.—who have achieved such remarkable results with the carrier-current principle, have also employed these voice-frequency methods; and Siemens and Halske in Germany have worked along similar lines. The latter have issued an interesting pamphlet describing their system of "Tonfrequenzwechselstromtelegraphie." Using only telephone frequencies, fair distances can be spanned without repeaters by such systems, and, by employing the multiplex on each tone-selective circuit, two wires could provide 40 traffic channels. In the case of the Siemens and Halske system, the pressure used on the line is only 1 volt (underground circuits being free from weather and other disturbances), and therefore no trouble is caused in neighbouring telephone loops in the same cable.

Of course the plain multiplex, working duplex, can give 12 channels on a single wire without difficulty, and there is nothing inherently impossible in working the ordinary multiplex up to 12 channels each way simultaneously on one stable circuit such as an underground cable can give, should the improvement of terminal facilities create a demand for increased circuit facilities. Indeed there are grounds for contending that for the wire-splitting required by the new telegraphy, the unaided multiplex is superior to any other method on lines of considerable length.

(6) *They arise from lack of terminal facilities.*—Although telegraph circuit facilities greatly exceed present requirements, there is one respect in which the telegraphs are very deficient, and that is in terminal facilities, or, in other words. in machinery, which in most countries is still old, inefficient, clumsy and stupid. No doubt this will provoke a smile, and people will say that I, as a telegraph machinery merchant, am using the shoemaker's argument that there is nothing like leather. It is true, nevertheless. The terminal facilities are bad and incomplete, and it is because of the defective terminal facilities that the telegraph lags so far behind the telephone. Also, a large portion of telegraph traffic is still handled by the morse key. That is the same thing as using a pen. We have to use a pen to sign letters, and the morse key will always be with us; but letters are typed nowadays, and the typewriter keyboard should be as supreme in telegraphy as it is in business. That condition is coming rapidly. It is in full flood in the United States, and it is to significant developments in the United States that I want to call special attention this evening. The era is beginning when typewriter keyboards in the offices of business men will not merely type letters, but will type and transmit telegrams direct to correspondents in any part of the world. At last the missing link will have been supplied, and the telegraph service will secure the direct connection with business that has been so long the monopoly of the telephone.

In certain cases this is not a new development. For the past 10 years at least, the distribution of news, for instance, has been linked up directly from the news centres to the newspapers, and the news distributing network in English-speaking countries is cheap and quick and highly efficient. Also stock and exchange brokers in big centres like London and New York have not much to complain about, though the telegraph service will be improved, even in their case, by the increasing use of the typewriter keyboard. It is in connection with the banks, the big financial houses, large hotels, big stores, the railways, great industries and manufacturing plants, and, above all, the great farming industry, that a quicker, cheaper and more accessible telegraph service is badly wanted.

It is true that the telegraph has already been brought into offices and factories, but only to a relatively small extent. There are many firms using rented telegraph wires with morse key and sounder and morse operators, especially in the United States. In this country, stockbrokers and other firms use the telegraph to some extent; but they are hampered by the necessity of employing a skilled morse operator at each end of the line, and they cannot ring up anybody by telegraph, as they can by telephone. In other words their telegraph service is poor. It is cribbed, cabined and confined to one correspondent. Even now, stockbrokers, for instance in Glasgow, are each glad to pay nearly £4 000 a year for a private telephone line to London, though the telephone is notoriously bad for transmitting figures. A telegraph wire with the morse key would be cheaper, but it would be too slow. Competition is keen and a delay of 2 or 3 seconds in getting prices from London will result in business going to a competitor. There is also the considerable cost in wages of a morse operator at each end of the line.

Part 2.

THE TWIN REMEDIES.

(1) *Start-stop printers.*—The defective terminal facilities are due to a variety of causes; amongst others, to lack of faith and foresight on the part of telegraph administrations, and to a determination to buy cheaply by encouraging competition to such an extent that telegraph manufacturing does not pay. There is a natural tendency on the part of big consumers to encourage competition amongst manufacturers who supply them. The officials in the Reichspostamt in Berlin, long before the war, told me they liked to encourage competition, as they did not want the Reichspostamt to be at the mercy of one firm. This is the old Roman policy of "Divide and Conquer," and certainly printing telegraph inventors and manufacturers are a conquered race of helots who have made no particular profit up to the present out of printing telegraphy, or at least

profit in proportion to their efforts and to the service they have rendered. This has resulted in telegraph development work being starved and stunted. Also the inventive and development work has been very intricate and deceptive. Arrangements generally recognized as excellent have proved to be hopeless in practice; and other solutions, that looked unpromising, have proved to be good. Lack of capital, lack of experience, lack of knowledge of the best ways, have all put the brake on progress until comparatively recently. Printing telegraphy has been a tropical jungle, with the axe in use all the time, and no compass and no map. It is only within the last 10 years that the multiplex in its modern form, with typewriter keyboards and speeds to correspond, has won acceptance as the best machinery for trunk-line telegraphy; and it is only within the last 2 or 3 years that the second great step, probably the greatest step of all, has been taken in the successful development of start-stop printers. It is only just dawning on the telegraph world what an immensely important thing the start-stop printer really is, and that it is the long-sought missing-link which will complete the telegraph network and give the world a really efficient telegraph service corresponding to the highly satisfactory telephone service to which we have been accustomed for years. It is true that in some countries the telephone service is not efficient; but that is not the fault of the inventors and manufacturers. The equipment is available. In the case of the telegraphs the equipment has not been available until now.

Before dealing more in detail with the start-stop printer special attention must be devoted to the question of using start-stop printers like the teletype, through telephone exchanges or through special teletype exchanges. Telephone experts inform me that there are grave engineering objections to the employment of telegraph machines through a telephone exchange; but these difficulties are not insuperable. During a recent visit to Paris, I was informed that a telephone engineer in the French Administration had devised a very simple instrument which would enable the teletype to be worked through any telephone exchange. I was also informed that a second device for the same purpose had been invented in Paris. I have no details, but I suppose it is done by that modern lamp of Aladdin, the valve, which enables very feeble currents to be used. In France considerable importance appears to be attached by technical men to this possible development of using the teletype in conjunction with the telephone for working through telephone exchanges; but it would appear to be better in all respects to have separate teletype exchanges. (I may explain here that in this paper I am using the word "teletype" more or less as a generic term. What is said, of course, applies equally well to any other printer designed for the conditions of the service.)

Apart from the engineering difficulties, one argument that has been advanced against the use of the teletype or other start-stop printers on telephone lines, is that such an arrangement would load up the telephone wires in a very undesirable manner. Subscribers to the telephone service buy the right to communicate with other subscribers, and if the other subscribers block up their wires with teletype as well as telephone communication, the result will be either that there will have to be special teletype as well as telephone wires, or the engaged signal will be heard much oftener than now and subscribers will not get what they pay for, namely, quick telephone service.

There are two answers to this argument. In the first place, if a subscriber loads his telephone line to such an extent that other subscribers have difficulty in getting through to him, the proper remedy is for him to get another telephone line, and in fairness to other subscribers the telephone authorities quite rightly insist on his doing so. The other answer is that the use of the teletype will not in this generation exceed, say, 5 or 10 per cent of the telephone calls, and the effect of this on the telephone traffic load would be trifling—and it would be much less if the subscribers making much use of the teletype had separate wires.

(2) *The teletype exchange.*—Evidently, however, the separate teletype exchange is the best arrangement; but this does not mean that there will be separate teletype exchange buildings. The telegraph traffic would not warrant such expense, except in a few special cases. By a separate teletype exchange I mean a small separate section in a telephone exchange devoted exclusively to start-stop telegraph circuits. It will be seen that such provision for teletype work will be sufficient if we realize that a total of 50 000 teletype exchange subscribers in London would probably not be reached for many years, though much will depend on the price of the teletypes. If they ever come down to the price of typewriters (and this is a possibility within the next 25 years) the number of teletypes in use would grow immensely, and no business man could afford to be without a telephone, a teletype, a typewriter, and a typist. The problem of the next year or two, however, will be to provide for perhaps 1 000 or 2 000 teletype subscribers. To this number would be added the local post offices and telegraph substations, telegraph offices in big hotels and stores, and also a big central teletype exchange at the Central Telegraph Office in London, for handling all the telegraph traffic reaching that office. Clearly 1 000 or 2 000 teletype subscribers divided over 100 telephone exchanges in London would not cause much inconvenience by the requirement of a special teletype section, and even 50 000 teletype subscribers would only average 500 for each exchange. On the other hand, probably most of the teletype subscribers would be concentrated in the City, and it would be cheaper and quicker to take them direct to the central teletype exchange at the Central Telegraph Office.

The teletype exchange equipment would be substantially the same as for telephones, and, as the maintenance and supervision would be the same and by the same staffs, the cost of a teletype section in a telephone exchange would therefore not be great.

Although there are engineering difficulties in working telegraph apparatus through telephone exchanges, it ought to be practicable for a subscriber having one telephone line and a teletype to ring up the telephone exchange and say "teletypes." He would then be plugged through to the teletype section, and it would appear to be a simple matter for the teletype section to cut off his telephone loop completely from the telephone exchange and connect it to the teletype section. Wiring alterations would have to be made, but the alteration for each subscriber ought not to be great or costly. The subscriber having got through to the teletype section, a switch in his office would enable him to cut out the telephone and cut in the teletype. He would then teletype to the teletype exchange stating his requirements, and he would be put through in the same way by the aid of the telephone in the case of a local call, or direct to the central teletype exchange for a trunk or long-distance call, and he would then have his message typed direct at its destination. The *sine qua non* for improvement of the telegraph service is close co-operation between the telegraphs and the telephones, and the foregoing teletype call is an illustration.

(3) *Resulting in the new telegraphy.*—The teletype exchange plan, if it succeeds, will in time effect a complete revolution in telegraph methods and organization in head telegraph offices, especially in large cities, which will be provided with automatic telephone exchange equipment for the teletype exchange. The telegraph operator belongs to a doomed profession and he will disappear, for the same reason that the telephone girl is being driven out by the automatic telephone switches. On the other hand, there will be an increase in the number of engineers, and gangs of mechanics will wander about in the otherwise silent and deserted galleries at St. Martin's-le-Grand, and the screwdriver and the soldering iron will take the place of the morse key and sounder. The general public will continue to write out their occasional telegrams and hand them in at the nearest telegraph office. There, calls will be put through to Glasgow or Manchester or elsewhere, and the telegrams will be teletyped direct to their destinations. Every hotel and public place will have a teletype for delivery and reception of telegrams. There will be teletype call-offices or pay-stations at hotels, big stores, underground stations, post offices and other convenient centres, where it will be possible to use the teletype on similar terms to the telephone in similar circumstances, namely, payment of a sum according to time and distance.

The teletype can be left ready for receiving messages all night. Unlike the telephone, the teletype records messages without human assistance, and when the business man comes to his office in the morning he will find telegrams and cablegrams that have arrived during the night or early morning. For example, if we are in a country village in Kent and late at night we receive by telephone an important telegram from McDonald and Co. in Glasgow, we shall telephone our reply as a phonogram to the nearest telegraph office. There a teletype call will be put through to McDonald and Co. in Glasgow and the message will be printed direct on a teletype in their silent and deserted office ready for action when the office opens in the morning. There will be only one transmission and only one typing of our message, and there will be no " circulating " and no telegraph operator and no message-boy in Glasgow. The message will go direct and be recorded without human labour. Kleinschmidt makes a feature of this point in his advertisements of his start-stop printer. It records messages all night in empty offices at railway stations ready for the staff in the morning.

As another example of the new telegraphy, let us consider a large manufacturing plant, say in Newcastle, equipped with start-stop printers, such as teletypes. There would be a private-branch teletype exchange, as well as the usual private-branch telephone exchange. Orders and other departmental communications that have to be typed would go through the private teletype exchange, and any department could at once send a telegram through the private teletype exchange on to the Post Office telegraph wires, let us say, to a firm in Glasgow, the Post Office plugging the department direct through to the Glasgow firm, and the department would get a reply probably at once, or at any rate with only a few minutes' delay. That would be far more convenient and cheaper and quicker and more accurate than the telephone. Similarly, any department of the big manufacturing plant could receive outside telegrams direct, with substantial saving of time. In future days when there will be a dozen of the new permalloy Atlantic cables in use, each working at 300 words a minute in each direction simultaneously, and all fitted with sextuple duplex multiplex, there will be no difficulty in sending a message from any department of the manufacturing plant in Newcastle to San Francisco or other American city, and getting a reply within 10 minutes, subject always to the conditions of daylight between Europe and America. The circuit facilities will be still greater when half a dozen wireless beams work across the Atlantic, each at 300 words a minute.

Another important feature of the new telegraphy will be the assistance it will give to small newspapers which cannot afford to have a private wire of their own. Small country, local suburban and weekly journals would be glad if they could get news on 3-minute teletype calls. It would be cheaper than the telephone, more reliable and much more convenient, as the teletype would print the messages ready for use. In most cases these teletype circuits would be superposed on telephone lines. The teletype exchange is undoubtedly going to have a large effect on the distribution of news.

(4) *Printing telegraphs for farmers.*—Still another example of the new telegraphy must be given because of its great importance, and because it will open up an entirely new field for telegraphy. It may sound ridiculous to people in Great Britain, where the farming industry is so backward and unprofitable, but it is a fact that it is to the farming industry—the greatest and oldest of all industries in all countries—that the start-stop printer will render the most important service. In other lands, and especially in new countries, there is a very large and prosperous farming and plantation, and station- and ranch-owning class, especially in North America; and market prices are just as vital to such farmers as to any stockbroker; and another thing vital to the man who ploughs the land, as well as to the man who ploughs the sea, is the weather. The sailor must rely for his weather reports on his barometer and wireless, but not so the farmer, who can also have his teletype.

In Australia the inch of rain is divided into 100 points, and weather reports are distributed and put up by

Government on the bulletin board at every country post office or railway station; and the keen interest that the settlers and station-owners take in these weather reports is astonishing. The fact that 3 points of rain have fallen at a township 30 miles away is a matter of intense interest. Rainfall or no rainfall spells wealth or ruin to the farmer and station-owner. In other lands warnings about storms and blizzards are not less important. Prices of sheep and cattle, pigs, wool, hides, wheat, butter, coffee, tea, rubber, and other farm, station, plantation and ranch produce, not only at the nearest local market, but in the big markets of the country, and also the world prices, bring wealth or poverty to the man on the land. Next to the stock market and produce brokers, there is no other man in the world so interested in prices as the farmer, and the farmer's concern about the weather is proverbial. The latest market and weather reports are so valuable to him that he will pay gladly for them, just as the stock-broker pays willingly for his ticker service. Hitherto the farmer has never had an opportunity to pay for it. He will also appreciate getting a prompt service giving all the important news of the world.

The start-stop printer, for the first time, fills the requirements of the farmer for a stock-ticker service and it is far and away superior to any stock-ticker. The speed is greater, 40 to 80 words a minute; it will work over any distance, 5 000 miles if necessary; it can be superposed on the farmer's telephone circuit; it can be used on a farmer's party line jointly with other farmers; and it has a keyboard on which the farmer can send out messages as well as receive them. After reading the market prices he can give immediate orders on the teletype to buy or sell. By means of the teletype keyboard, he can communicate with his neighbours along the top wire of his fences. (In Australia, on the great sheep stations, the head station is always in communication with the outstations by telephone along the fencing wire.) Of course, start-stop printers are not suitable for the remote districts; they need an occasional inspection and a drop of oil, and also electric power to drive them. That is a fairly simple matter in the settled districts of the world, where also the distances are not so great as to render the cost of the telegraph or telephone line prohibitive; but even in newly opened-up country with a sparse population there is always the local post and telegraph office (often the general store and centre of gossip for the whole countryside), and a teletype at such a centre would pour out invaluable news of the world, including prices and weather reports, printed on tape ready for the bulletin board, giving a flood of news that could not be received in any other way. In such a case the electric power problem would be difficult, but not insoluble.

Taking more particularly the United States, because of the enormous number of very prosperous farmers in that country it is obvious that farm news-distributing organizations will spring up all over the country for the supply of market and weather reports and other news of interest to farmers, and the farmers will have the opportunity of talking back on the keyboard of the teletype. It may be said that it will be cheaper for the farmers to listen to market and weather reports broadcast by wireless; but a little consideration will show how hopeless that is. To get wireless reports the farmer or some member of his household would have to be in attendance at fixed hours to write down the wireless news. The idea of a farmer or his wife or family trying to note down market prices rattled off quickly by wireless is absurd. Even if this were possible, there are the inaccuracy of wireless, interference troubles and atmospherics, and there is no way of answering back. The only practical plan is a tape-printing teletype recording any news accurately in plain type without human labour, and on duty at all hours. The farmer and his household can read the news and market reports at any time at leisure and he can also get a service of general news. The market reports can be far fuller, as well as far more accurate, than would be possible by any wireless distribution, and far quicker than through any newspaper. The teletype will bring the farmer right into the Chicago Wheat Pit and other market centres. He will know and compare the latest prices straight from the sales of his local market town and also from the big centres of the world.

The prosperous farmer in America and many other countries has his telephone and his motor-car as a matter of course, and it is certain that as soon as the opportunity presents itself and he gets accustomed to the idea, he will add the teletype to his telephone and his wireless set, and in time he will value his teletype above all his earthly treasures. When the farmers of the world adopt the teletype superposed on their telephone circuits, we shall have real telegraphy—a vast printing-telegraph network of wire nerves linking up all industries and all countries.

(5) *Starting the new telegraphy.*—That this idea of teletype exchanges on the lines of telephone exchanges is not a mere speculation is shown by very interesting developments in the United States. Realizing the importance of the machines, the Western Union Telegraph Co. has been giving careful attention to the development of start-stop printers for some years, and this class of machine appears at last to have reached a sufficiently reliable and permanent form to justify the Western Union in offering to furnish its patrons with printing-telegraph service. That will, of course, include circuits and printers connecting patrons to the head telegraph office of the Western Union in each city. The Western Union will also no doubt supply what is known as point-to-point service—that is to say, will connect any two points desired by telegraph lines and start-stop printers. In other words the Western Union is arranging to sell telegraph typewriter service to business men and firms—that is to say, to subscribers. Assuming that the scheme proves popular and commercially profitable, then the Western Union will have hundreds of subscribers in New York alone, to say nothing of other cities. Inevitably the company will have to supply intercommunication between these subscribers. The object of the subscribers or business men buying printing-telegraph service in New York will be to send and receive telegrams quickly, and they will want to do that between each other and also over long-distance telegraph wires with subscribers in other cities. It is clear that if the Western Union can secure a considerable number

of telegraph typewriter subscribers in the leading cities of the United States, then the printing-telegraph exchange and the new telegraphy will have been successfully inaugurated. The Western Union being a very big, old telegraph company with great resources and 50 years of accumulated experience of printing-telegraphy in all its forms, and operating in a great and highly industrialized community, is specially qualified for making a success of the new telegraphy, if that is commercially possible under present conditions.

Another element that makes for progress is competition, and the Bell Telephone Co. is starting to sell telegraph typewriter service to business men in Chicago on similar lines to the Western Union. Chicago, being a great business centre in the heart of the United States, is very favourably situated for the growth of the new telegraphy. I have a copy of a handsome booklet, artistically illustrated and persuasively written, which the Bell Telephone Co. is issuing in Chicago, with the idea of inducing business men to buy printing-telegraph service. It does not propose to establish a printing-telegraph exchange, but simply to supply wires and printing-telegraph apparatus to enable firms to link up their various branches and offices by a private printing-telegraph wire system. Although there is no mention in the pamphlet of a printing-telegraph exchange, a moment's reflection will show that, just as in the case of the Western Union, the existence of a number of private printing-telegraph networks each linking up the various branches of one firm's activities in Chicago would soon lead to a demand for intercommunication facilities, and that would result in a printing-telegraph exchange. If the Bell Telephone Co. finds that selling printing-telegraph service to business men and firms in Chicago is profitable, then it will lead inevitably to the teletype exchange and so on step by step to the new telegraphy. The pamphlet is called: "The Doorway of Opportunity"—"Telephone Typewriter Service"—"It Typewrites by Wire."

(6) "*The Doorway of Opportunity.*"—The booklet describes some of the attractive features of the telephone typewriter service, and as the subject is of such great importance I quote some of the paragraphs as follows :—

> "Modern business of to-day is very largely conducted by means of the telephone and the typewriter. It has long been felt that if these two giants of industry could be combined and efficiently operated as one unit, we would have made long strides in furnishing the business world with the last words in telephony. After years of study and research work, we feel that we are now able to furnish to our patrons a machine that will efficiently combine these two. This machine is known as the Telephone-Typewriter.

. . . . .

> "This is not a new and untried service. For a number of years it has been in daily use by modern business organizations for the rapid and constant transmission of typewritten communications between the executive office—branch offices—warehouses—mills—factories located in distant cities, by the Long Lines Department of the American Telephone and Telegraph Co. in transmitting official communications to all of their offices located in principal cities, and by the Associated Press in accurately and expeditiously distributing current news simultaneously to its newspaper clients.
>
> "Messages can be typewritten in your office and come out at one or more of your local or distant offices with a home record. No operator or attendant is necessary at the receiving end.
>
> "It will do practically anything a typewriter can do and can be operated by anyone who can operate a typewriter.
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> "This service is now being used by a number of modern business organizations, Press Associations and newspapers with very satisfactory results in the handling of messages, letters, routine matters, such as operations, administration, sales, purchasing, statements of stocks on hand, shipments, orders, quotations, accounting and for the dissemination of news.
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> "This service may also be used for conference purposes between groups at different offices, locally or in distant cities, thus effecting the saving of a great amount of time and expense incurred by travelling.
>
> "Your branch office is no farther away from you than the telephone typewriter."

. . . . .

> "Telephone Typewriter Service will be found dependable and economical as an adjunct to the telephone for the transmission of communications in factories, banks, hotels, and mail-order houses; between the sales, order, credit, accounting, and shipping departments and the executive offices of an establishment; accurately and privately without loss of time or error in giving or taking instructions.
>
> "We have established a Telephone Typewriter Service department and will, without charge, make a study of your communication requirements to ascertain if the Telephone Typewriter Service will be advantageous to you in the conduct of your business."

A skeleton map is given showing combination circuits for the telephone typewriter service within the city of Chicago and nearby territory. Five circuits are shown, each connecting in series from seven to nine city and suburban centres. One line, for instance, connects the General Office in Chicago with branch offices, Factory, Maywood, Melrose-park, Wheaton, West Chicago, Aurora and Elgin. The illustrations show the Morkrum typewheel teletype, which prints on a tape at 40 words a minute, and the Morkrum typebar page teletype which prints on sheets of paper at 60 words a minute. The pamphlet concludes with the statement: "Our telephone typewriter department will appreciate the opportunity of calling on you and explaining the service more in detail."

The publication of such a booklet by a great concern like the Bell Telephone Co., and the corresponding movement by the Western Union, show that this paper cannot be dismissed as idealistic dreaming.

Assuming that teletype exchanges are successfully established by the Western Union and the Bell Telephone Co. in the leading cities of the United States, then it would be a comparatively short step to link up these teletype exchanges by trunk telegraph wires all over America. Of course, in the case of the Bell Telephone Co., telegraph circuits superposed on its telephone lines will be used, and various systems of multiplexing the trunk wires will also be put into operation more extensively than now.

(7) *Some results.*—The result of this development will be that a business man in New York, wishing to communicate with a business man in San Francisco, will get through to his teletype exchange and be connected to his San Francisco correspondent, with a certain amount of delay similar to, but less than, that which takes place in putting through a telephone trunk call. Once connected, a typist in his office will teletype the business communication, and in many cases an immediate answer will come back on the teletype. In this way business will be linked up directly to the telegraph network, just as it is now linked up to the telephone service, and the present telegraph delays will be eliminated. There will be much greater accuracy than with the telephone and there will also be the advantage of much cheaper rates of communication than are possible with the telephone service; multiplexed telegraph wires being far cheaper than telephone wires. In fact, in the case of an immense concern like the Bell Telephone Co. the use of its telegraph circuits in this way will really be the utilization of a by-product of its telephone business. The same remarks apply in the case of the British Post Office and other administrations supplying telegraph and telephone service. The economies that will be effected by cutting out all telegraph labour, and by transmitting and printing direct, have already been explained.

One remarkable idea in connection with the proposed teletype exchange scheme hinted at in the Bell Telephone pamphlet is its use for conferences, because the teletypes at each point could be linked up so that all would record the messages transmitted at each station. Half a dozen business men, 10 or 20 or 1 000 miles apart, could get together by teletype for a conference at very short notice. The teletypes in each office would record the minutes of the conference, including the discussion and the full text of the resolutions passed or decisions arrived at, and each member of the conference would have a complete typed record of the proceedings in his office. Also, the conference would be secret. There would be no overhearing or eavesdropping. The teletype language is spoken and understood only by teletypes, and the code-bars can be mixed at will to scramble the messages and make them doubly secure against overhearing by outsiders. There is something deeply impressive about this idea of a conference taking place between men hundreds or even thousands of miles apart, with no sound but the slight tapping of the typebars, and the men in silence, each alone, watching the words being recorded, or transmitting on his keyboard. Not even a secretary need know about it. The saving of the precious time of business or political magnates would be great, and the acceleration of the business, which could not otherwise be transacted until the members of the conference had actually met after much delay and railway travelling, would be important. Vital decisions might be made in this way possibly a week sooner than would otherwise be possible. Take, for instance, the British Government; an urgent meeting of the Cabinet could be held and decisions arrived at with the members of the Cabinet scattered all over the country. Members of Parliament could confer with their constituents, and even international conferences could be held in this way with every advantage of "secret diplomacy." The only parallel to such a teletype conference would be a wireless telephone conference between heads of Governments, to which all the world would listen in, and we should have "open covenants openly arrived at."

Returning again to realities, the new telegraphy with its cheap and quick long-distance communication will be an immense boon to the industrial and financial world, and many interesting practical results of political and social importance will flow from it. Two may be briefly referred to as illustrations. One will be the upsetting of the present balance of telegraph and telephone interests in the United States, the probable result being consolidation under the control of the Interstate Commerce Commission. The new telegraphy will lead inevitably to competing teletype exchanges in each city. This development will be as great a nuisance as competing telephone exchanges, and the public convenience will be best served by consolidation, the result being a telegraph and telephone organization in the United States by far the largest and most remarkable in the world. Another result will be increased impetus to the extension of the Garden City movement and decentralization. Obviously the great book-keeping industry can be carried on in low-rented premises in pleasant surroundings in the country just as well as in London city offices, dirty, smoky and dark, and costing exorbitant sums for rent. The teletype and the telephone bring the Garden City book-keeping factory alongside the London city office, which will contract into a showroom and calling-place for visitors. This process of decentralization in connection with factory work has been going on for years and the teletype and telephone will extend and accelerate the process.

As these great changes will be brought about by the start-stop telegraph printer, it will be realized that this is a machine of outstanding commercial and political importance.

(8) *How the teletype exchanges will work.*—Just as in the case of the telephone service, there will be private-branch teletype exchanges, and these will of course connect up to the main telegraph network of the country through the city teletype exchange. In Chicago, for instance, the Morrison Hotel is equipped with 32 of the little tape teletypes, forming an internal intercommunicating system in all respects like a private-branch telephone exchange, and other American hotels are being fitted in the same way. Naturally, these private-branch exchanges will be linked up with their respective city teletype exchanges and in this way put in telegraphic communication with the whole of America and, in the course of time, via the new 300-words-a-minute Atlantic cables, also with Europe.

It is possible that the number of teletype subscribers in one city may not, for many years, be more than one exchange could handle, and in that case the teletype exchange would be situated in the chief telegraph office of each city. This, however, would depend on the size of the city and the length of the local lines to connect subscribers to the teletype exchange. It is a detail that will be settled by local circumstances. In London, for instance, there will probably be teletype sections in most of the telephone exchanges, with a big central teletype exchange at the Central Telegraph Office.

This telegraph service will be paid for just as the telephone service is paid for. There will be a local message rate, and time and distance rates for trunk or long-distance messages. Fortunately for this new development of the telegraphs, most of the problems have already been worked out in connection with the telephones, and telephone technique will be used in the teletype exchanges and wherever else it can be employed with advantage. The mechanism of telephone exchanges, with some modifications, will do equally well for teletype exchanges. A subscriber will be able to ring up any other subscriber, with all the usual " engaged " and other signals; but the teletype subscriber will have an advantage that he cannot have now on the telephone trunk service. Suppose he is a London merchant. He will be able to ask the Central Telegraph Office in London to put him through to Glasgow, and he will be put through exactly as now in the case of a trunk telephone call—with this important difference, that the delay in getting through will probably be small in the case of the telegraph service, perhaps not more than a minute or two, or even with no delay at all, because there will be far more " channels of communication " available to Glasgow and other cities than would be financially possible in the case of the telephone. A single telegraph wire will give at least six separate channels, compared with one channel of communication on two telephone wires. Take, for instance, some results obtained by the Western Electric Co. on four aerial wires between Chicago and Omaha, 450 miles. These four wires gave three telephone circuits, four earthed telegraph circuits and no less than 20 two-way carrier telegraph circuits, or more than six " channels of communication " on each wire.

In London alone about 18 minutes' delay would be cut out by getting direct in this way to Glasgow, and even if the message were sent by the customer by telephone as a " phonogram " it would still go to the phonogram room, where it would be written down and sent " circulating " until it reached the Glasgow circuit. On the average in a provincial telegraph office in Great Britain the " transit time," that is to say, the time elapsing from the handing over of a telegram by the public until it reaches the circuit over which it is to be transmitted, is about 5 minutes, and in London about 8 minutes. The average " circuit delay," that is to say, the time that a telegram has to wait its turn at the circuit before being transmitted, is about 10 minutes. This circuit delay corresponds to the delay in getting through on a trunk or long-distance telephone line. Hence, in provincial offices there is an average delay of 15 minutes from the time a message is handed in to a telegraph office until transmission begins over the telegraph line. In London this combined delay of transit time and circuit delay averages 18 minutes. There is also telegraph messenger time, which may into anything from 5 minutes to half an hour or more, depending on the size of the staff of messengers available and the distance to be traversed. The aim of the new telegraphy is to cut out all these delays.

With teletype exchanges in operation, manual " circulation " of telegrams will give place to manual switching and, finally, to automatic switching. That is to say, the handling of telegrams will be greatly reduced, and instead of many telegrams being rewritten several times in the course of their wanderings, they will go straight through to their destinations, like the modern loaf of bread, without being touched by human hand. At present some telegrams have actually to be rewritten four or five times. A message handed in at a suburban office in London is rewritten at the Central Telegraph Office and then telegraphed, say, to Glasgow, where it is once more rewritten and sent to another suburban telegraph office, and once more rewritten before being delivered by a message-boy.

Obviously, cutting out the circulation of telegrams will eliminate great waste of time and labour, especially in big cities like London. Telegrams received at the Central Telegraph Office in London have to go through an elaborate journey before reaching the London end of the telegraph lines over which they are to be transmitted. They are taken in and dealt with by counter clerks, blown through pneumatic tubes, shuffled at distribution tables, pigeon-holed, and then taken to their respective circuits for transmission. Delay also takes place at the receiving office. There are similar delays in large offices where telegrams have to be retransmitted. They have to be circulated until they reach the right point for retransmission. The start-stop printer and the teletype exchange will short-cut all this delay and waste of labour. Also the ridiculous time- and labour-wasting process of checking and counting the number of words in telegrams at every stage, unavoidable by present methods, will disappear. One count will be sufficient, and when transmission is direct from the sender to the receiver of the message there will be no counting at all, but a charge by time and distance.

With a start-stop printer and the teletype exchange the subscriber in London would communicate, clear of all obstructions, direct from his office in London to the office of his correspondent in Glasgow, who could, if the message permitted, reply at once. Obviously this should be considerably cheaper than sending a telegram in the ordinary way, because no telegraph operators would be required. The work of sending the telegram would be done by a typist in the merchant's office, and all the handling of the message in " circulating " it to the Glasgow circuit would be cut out. The cost and delay of the telegraph messenger would also disappear. In addition, as the cost of the telegraph line used in sending the message from London to Glasgow would only be about one-twelfth of the cost of a telephone circuit, the message ought to cost much less than a telephone message to Glasgow. Also the duration of a teletype call could be reduced, compared with a telephone call, from, say, 3 minutes to 2 minutes. The latest start-stop printers work well up [illegible] words a minute, and a good typist can do 60 words a minute easily. Hence 120 words could go through in 2 minutes, or 10 times as many words as the usual 12-word telegram for which the Post Office charges a shilling. Clearly there would be great economy to the Post Office through the adoption of this form of telegraphy, and time- and distance-rates could be arranged that would be profitable to the Post Office and yet attractive to business men.

Of course, speaking in a general way, there is nothing new in all this, and therein lies good hope for success. There is nothing idealistic about it, and it is only a slight extension of what is already done. The telephone does it already, and substituting a telegraph transmitter and receiver for a telephone transmitter and receiver ought not to disturb the most conservative mind. Further, there is nothing particularly new in this, even from a telegraphic point of view. There are telegraph concentrator systems in all important telegraph offices, now used to concentrate and save labour, but which may be regarded as germs of telegraph exchanges. There is also the London intercommunication switch designed by the present Engineer-in-Chief of the British Post Office, Colonel T. F. Purves, and installed in 1902.* This may be described as an official and not a public telegraph exchange. It is a real telegraph exchange interconnecting London local telegraph offices; but it does not attempt the final linkage to business firms, because it uses the morse key, an instrument not commercially practicable in such cases. Colonel Purves's book contains some very interesting information on the subject of "through-switching" of telegraph exchanges. It was carried out in England as early as 1854, but it was used to connect telegraph office to telegraph office and not subscriber to subscriber. The telegraph exchange plan was used and abandoned by other administrations many years ago, but Belgium persevered with the arrangement and it is still in use in that country for morse telegraph working. Briefly the scheme is approximately as follows:—Station A, connected by direct wire to station B, has a telegram for, say, station F, whom he calls on his line to B. There may be more than one route from B to F, via, say, C, D, E, or G, H, J; the more appropriate route is selected by B and the call is passed on until F replies to A.

As a matter of fact the London intercommunication switch, after having been in use for 20 years, has gradually been killed by the competition of the telephone, and it is understood that the British Post Office proposes to abandon it. The intercommunication switch was primarily designed to link up about 200 local London telegraph offices so that telegrams could be transmitted direct between any of these local offices by way of the central switching exchange. Obviously this is not a subscriber system like a telephone exchange, and it does not possess the great advantage of the telegraph over the telephone of cheap long-distance facilities. It is a telegraph exchange attempting to compete with the telephone on ground most favourable to the telephone. Naturally the telephone has gradually drained away the traffic until there is very little left for the intercommunication switch to handle. People will not spend a shilling for a 12-word telegram in London with about an hour's delay, when they can send and receive 1 000 words with no delay and for less than twopence by telephone. A local London service of threepenny telegrams might revive the intercommunication switch, especially if combined with start-stop printers. Also to extend the area of service, so as to bring in the advantage to the telegraph of longer lines, might help; but it is on the subscriber, or what might be called the "direct user," that the success of the new telegraphy will depend.

It is necessary to point out the weaknesses of the London intercommunication switch, because its want of success will probably be used as an argument against the new telegraphy. A little space must therefore be devoted to it. Apart from the deadly competition of cheap short-line telephones at about one penny per message and answer, a telegraph exchange relying on the morse key and sounder cannot hope to be a success; first, because average private users cannot afford the expense of keeping a morse operator, although they can and do habitually keep girl typists; and secondly, because a morse operator sending needs a morse operator receiving. The start-stop printer solves these two difficulties. It supplies the private subscriber with a telegraph machine which his typists can use after a few minutes' practice and without additional expense for labour, and it substitutes an automatic and reliable machine in place of the receiving morse operator. In fact the morse operator will not be required. One typist can attend to half a dozen teletypes if the traffic is not heavy, and the receiving typist will be able to send at any moment when the line is free. There is also a possibility of some kind of duplex working, giving simultaneous communication each way on the one wire.

At present, in the case of these local London telegraph offices linked up by the intercommunication switch, the Post Office, and not subscribers, has to pay the wages of the morse operators at both ends of the lines. The teletype exchange with private subscribers will relieve the Post Office of payment of wages for a gradually increasing portion of the telegraph traffic. Another point not to be forgotten is that the start-stop printers will enable the typists to do about double as much work as with morse key and sounder, and a receiving typist will not be required for each printer. The engaged signal has seriously reduced the economic efficiency of the intercommunication switch, because paid Government operators are kept waiting. With private subscribers any loss due to engaged signals will not fall on the Government any more than in the case of telephones. In the case of a typist attending to several teletypes in a local telegraph office, acknowledgment of receipt of messages presents some difficulties, but a bell or a lamp signal at the end of messages would warn and guide the attendant in giving acknowledgments of receipt of messages without unreasonable delay even if half a dozen printers required attention.

Another plan would be to use the reservoir effect obtainable by means of receiving-tape perforators and retransmitters. This, however, introduces complexities, to say nothing of perplexities, and probably the best plan is the "engaged" signal if a message cannot be accepted at once.

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* See "Telegraph Switching Systems," by T. F. Purves.

It is to be noted that even the connecting-up of outside customers to telegraph offices is not new. The use of the Steljes step-by-step printer in this way is very old in England, and a similar arrangement has been in use in Germany for years, the little Ferndrucker of Siemens and Halske being very largely employed for the purpose. This, however, like the Steljes, is merely a step-by-step printer like a stock-ticker, provided with a typewriter keyboard, and the speed is low, about 25 words a minute; and, being on the step-by-step principle, neither the Steljes nor the Siemens Ferndrucker is satisfactory for working much beyond city limits. In "Telegraph Switching Systems," Colonel Purves mentions that ABC telegraph exchanges between ABC subscribers for direct telegraphy were in actual use in England in the late seventies, but the telephone swept them away. This is of real historical interest, because it shows that the telegraph would long ago have developed on the lines indicated in this paper if modern printing-telegraph machinery had been available. As it was, the telephone, when it arrived, swept all before it. Whether the telegraph can recover lost ground now that the machinery is available, is purely a commercial question.

The really new feature of the service about to be put into operation in America is the use of start-stop printing-telegraph machines capable of high speed, 40 to 80 words a minute, tape-printing or page-printing, and able to work with ease over thousands of miles, and capable also of linking up with the multiplex telegraph network of the country, and with the potentiality of sending messages automatically all over the world. That is quite new and of the greatest importance, and it is the start-stop printer that has made this development possible.

(9) *Linking up the telegraph network.* I have referred to the possibility of linking up the start-stop printers with multiplex trunk circuits. A good deal of work has been done in this direction by the Western Electric Co., and several years ago it exhibited in London an installation of its multiplex system with start-stop printer extensions from various channels. In a description issued in the course of its demonstration, the company mentioned that the start-stop printer had been in duplex operation on a circuit 1 000 miles long between New York and Chicago with one girl operator at each end. This circuit was obtained by superposing on a telephone line, and the daily average load for 9 hours was 22 000 words, or about 1 000 messages. The company also mentioned that it is possible to provide intercommunication between a number of offices by means of the start-stop printer when working simplex, and also to use selectors by means of which any one of a number of stations may be called, the printers at the other stations remaining idle while a message is being printed at the selected station. These facilities can of course be supplied by any other modern start-stop printers such as the Morkrum teletype, the Kleinschmidt, the Creed direct printer, or the Siemens and Halske.

The Western Electric Co. has some interesting patents on methods of linking up start-stop printers with channels of multiplex installations. There is, for example, British patent 165783, showing various branching arrangements for connecting up several cities with both forked multiplex and start-stop printers. Fig. 1 in the above patent, for instance, shows a Y-forking arrangement comprising three terminal multiplex distributing stations arranged for four channels from each terminal multiplex station, through a repeating station, to each of the other terminal multiplex stations, and also illustrates how one arm or channel of the multiplex distributor at, for example, St. Louis, may be extended by means of start-stop equipment to two outlying cities or stations. It is also pointed out that any or all of the channels of each terminal multiplex station may be extended, if desired, to an equal number of distant or outlying stations by means of start-stop equipment.

In France, forked and series working with the Baudot multiplex has been in use for many years, and the French have wonderful methods of linking up various cities on one wire by the multiplex. The Western Union has likewise been doing a good deal of work in this direction, and those who are interested will find it fully dealt with and illustrated by clear diagrams in Mr. H. H. Harrison's book on "Printing Telegraph Systems and Mechanisms"; but, to refresh the memory of those who are familiar with the subject and to enlighten those who are not, in Fig. 2 two diagrams from the Western Electric patent above referred to, with the addition of start-stop printers to each channel, and teletype exchanges in the cities, are given.

Fig. 2 will help us to realize the enormous extension of telegraph facilities rendered possible by the start-stop printer. It represents two wires from New York via Pittsburg to Chicago, one of the two wires having a branch from Pittsburg to St. Louis. These wires are equipped with multiplex printing-telegraphs working quadruple-duplex, giving four channels of communication simultaneously each way, solid lines representing channels working in one direction and dotted lines channels working in the other direction. The small rectangles marked M indicate sending and receiving sets on the multiplex. The rectangles marked S are start-stop printer extensions linking up to the multiplex channels. The rectangles SS are a number of start-stop printers in series on one wire, selective callers enabling any one or more of the SS sets to be called up and communicated with. The teletype exchanges explain themselves. To complete the picture, subscribers are needed. They are scarce at present and hard to convince, but their numbers will grow geometrically as facilities extend, just as they did in the case of the telephone.

A great advantage that the telegraph possesses over the telephone is that a telegraph message can be stored up at any point where there may be a "bottle-neck" until its turn comes for transmission. A telegraph operator usually has several telegrams in hand, which he transmits one after the other. They wait their turn. A telephone message cannot wait. In a vast telegraph network such as that contemplated in this paper, bottle-neck is a factor for which provision must be made. The excess in the supply of telegraph circuits last for ever, and in any case there will be certain points where delay will be liable to occur at times, especially during rush hours. The flow of telegraph traffic is very irregular, and there will be advantage in having reservoir mechanism at bottle-neck points, such as ocean cable terminals. Hitherto the receiving tape-perforator has been neglected by telegraph traffic managers ; but it is possible that the receiving perforator will come into its own in the new telegraphy. A business man in New York will dictate a telegram, a typist will transmit it to the nearest teletype exchange, and it may succeed in going direct as far as Chicago, and all channels west of Chicago may be engaged for a time. In that case the message might be stored up as perforated tape ready for transmission to San Francisco as soon as a channel is available. Otherwise the messages, in such cases, could be received on printers and retransmitted in their turn on typewriter keyboards.

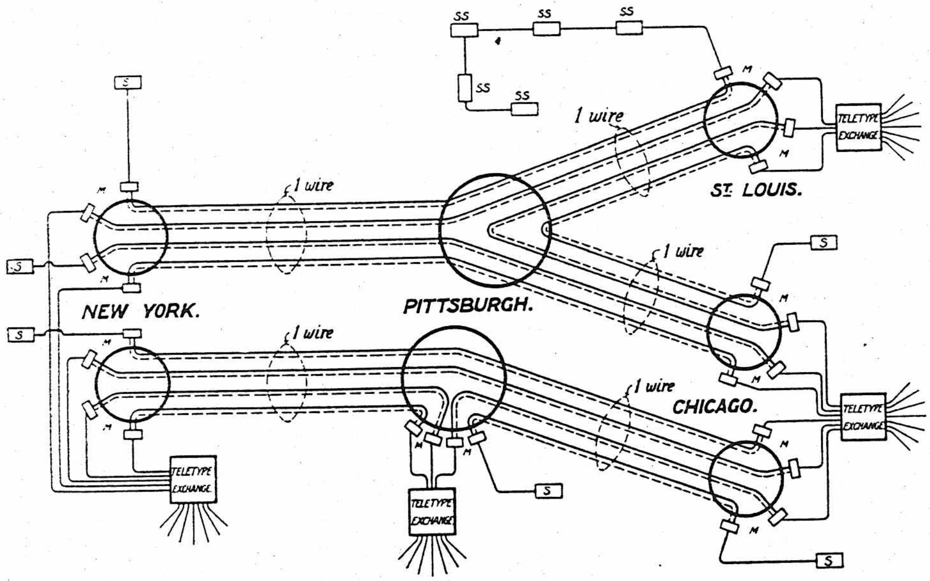


FIG. 2.—Diagram of multiplex printing-telegraph combined and extended by start-stop printers, single and in series, and with teletype exchanges.

Naturally there are many difficulties in the way, including human nature and established routines, and there are also serious arguments which have to be met. For instance, I can imagine the British Post Office saying to me : "Three-minute calls on your teletype exchange would be only 20 telegraph messages an hour per channel, and there is the loss of time in calling, answering calls, getting through, giving the line to the subscriber and disconnecting, which would diminish the output to perhaps 15 messages an hour, or even less. We can quite easily send 60 messages an hour by our present methods, as long as there is enough traffic, and at times we send 80 and 90 and even 100 messages an hour per channel. If your teletype exchange cuts down the average to 15 messages an hour, we shall have to charge more. Also our professional operators steadily employed on telegraph circuits will send far more messages than a girl typist suddenly called upon to send a message on the teletype for her employer. Quite obviously your teletype exchange would only be for big business firms and companies, banks, railways and the like. For the thousands and thousands of small men it would be useless. It would not pay them to use a teletype for one or two telegrams a week."

The best reply to this supposed criticism will be to quote a few figures. The financial advantage possessed by the telegraph when distance becomes an important factor is a powerful argument in favour of the long-distance telegraph and against the long-distance telephone, and the telegraph administrations will be glad to increase their profits by reducing their expenditure on wages by throwing the burden of transmitting and receiving telegrams on to the business community, and the business community will be glad to shoulder that burden in return for the boon of quick telegraph service. There is every indication that there is money in the new telegraphy, and if that is the case the matter is settled.

It must not be forgotten that the telegraph administrations and companies lease telegraph wires or "channels of communication" for long terms, 6 months or a year, and they will be glad to lease telegraph wires for 3 minutes, just as they lease telephone wires, if they can make money by doing so. The financial case for the new telegraphy will be realized after a little study of the table on page 262 giving the British Post Office annual charges for telegraph and telephone wires.

Taking, first, London to Birmingham, roughly about 100 miles, the Post Office will lease a complete telegraph wire during the day for a rental of £685 a year. There is no difficulty in getting six channels each way on one telegraph wire from London to Birmingham. Hence dividing £685 by six we get a rental of £114 a year per channel. Dividing this by 300 days in the working year, we get 7s. 7d. per day. Taking the business day at 8 hours, we get a rental per hour of a trifle under 1s., or only 0·2d. per minute. Assuming that the active time of communication is 3 minutes and that the time spent in connecting and disconnecting is 3 minutes, or, in all, 6 minutes per call, the rental would be only a trifle over 1d. for 6 minutes. Even if the Post Office tripled this rate and charged 3d. for a 3-minute teletype talk between London and Birmingham with a "no delay" service, it would be regarded by the business community as a godsend. The minimum for a London—Birmingham telephone call of 3 minutes is 2s. There is a big difference between 3d. and 2s., and the difference is still greater if we deduct the cost of postage, 1½d., which is saved in each case by using the telegraph or telephone instead of the mail. It becomes 1½d. extra for the teletype call of 3 minutes transmitting at least 100 words, and 22½d. extra for the telephone call, an advantage of 15 to 1 in favour of the telegraph, even over only 100 miles.

Now working backwards, the Post Office is to get 3d. for 6 minutes (a 3-minute call and 3 minutes connecting) on one channel between London and Birmingham. This is 2s. 6d. per hour, or £1 a day of 8 hours, or £6 a day for the six channels on one wire, or £1 800 rental for the year of 300 days. This is, of course, on the assumption that the wire is kept busy with calls every 6 minutes. Actually it is possible to divide up a wire between London and Birmingham into at least 12 channels each way, so that there would be a future possibility of penny teletype calls between London and Birmingham, exchanging about 50 words each way. In other words the business community will get an extremely cheap and quick telegraph service and the Post Office will get a greatly increased rental for its telegraph wires and will save the wages of operating staff at present employed handling telegrams. £1 800 a year should leave ample margin for the wages of the exchange attendants and for maintenance and other charges.

Approximate Annual Rentals for Lines.

	London to Birmingham	London to Manchester	London to Glasgow
	£	£	£
A telegraph wire, but not including apparatus ..	685	1 120	2 415
A telephone circuit with apparatus	905	1 520	3 350

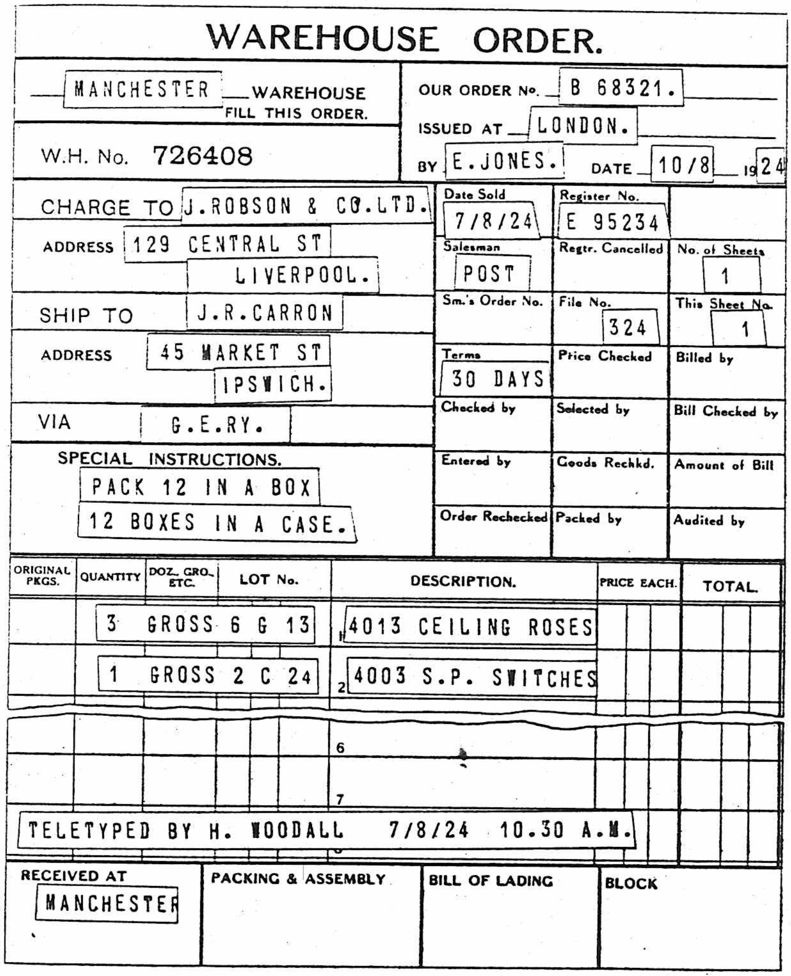
Now take London–Manchester, about 200 miles. The Post Office annual rental for a telegraph wire is £1 120. Five channels can be provided easily each way on the one wire, making the annual rental £224 per channel. Dividing this up as before we get 0·375d. per minute. Allowing 6 minutes per call as before, we get 2¼d. per call, and, tripling this as before, the call would cost a trifle under 7d. This charge would give the Post Office an annual rental of £3 500 for a London–Manchester telegraph wire. This again is on the assumption that there is a call every 6 minutes. A 3-minute telephone call to Manchester from London would be about 4s., compared with 7d. Taking London–Glasgow the rental is £2 415, and five channels each way can be easily secured. Hence, dividing by five, we get £483 a year rental per channel, or 0·8d. per minute, or 4·8d. for a 6-minute call (3 minutes communicating and 3 minutes getting through). If we increase this to 1s. as the rental for the 6 minutes, the total rental would be £6 000 a year for the five channels on one wire. A 3-minute telephone call to Glasgow would be about 8s. At present a shilling telegram from London to Glasgow would contain only 12 words, and it would take about an hour on the journey from sender to recipient and another hour for a reply. For the same shilling the new telegraphy would handle at least 100 and possibly 180 words, or a message and reply with little or no delay. At present the Post Office is working at a loss when charging 1d. a word, and at present the 180-word message would cost 15s.

Apart from the direct saving due to the new telegraphy, the wealth of the community would be increased by the speeding up of business resulting from the improved telegraph service. It is all a question of whether the scheme of public teletype exchanges is economically sound. It appears to be sound, but time and experience will tell in due course. There is no millennium for telegraphy; but as long as we do not expect too much from telegraph machinery and human nature, we have good reason to be hopeful about the great improvement in the telegraph service that will take place within the next 25 years, thanks to the multiplex printing-telegraph, the start-stop printer and the teletype exchange.

(10) "*Emptying the mail-bags.*"—An important aspect of the new telegraphy is where the increase of traffic is to come from, that will be necessary to pay for the new developments. Of course the new facilities will create a large volume of new traffic beyond the small annual increment due to growth of population and civilization; but, in addition, the increase of telegraph traffic will come by diversion of a certain amount of traffic from the telephones, and by what Delany used to call "Emptying the Mail-Bags." This is what American publicity men call a slogan; but it is a very poor one, because it is an impossible ideal, and the maximum that the telegraphs can hope to effect is a slight lightening of the mail-bags. Even 1 per cent of letters diverted from the Post Office would result in a great accretion of telegraph traffic.

The mails consist very largely of circulars, newspapers, printed matter, invoices, receipts, postal and money orders, cheques, drafts, securities, advice and receipt notes, waybills, bills of lading, drawings, blueprints, maps, plans, photographs—in short all the vast variety of business documents which cannot be telegraphed. There is also an enormous volume of private and domestic letters, of which only a minute proportion would ever be telegraphed, unless telegraphy became so excessively cheap that it could compete with the penny stamp and the postcard. There remains, however, a large volume of ordinary business correspondence which could be profitably sent by telegraph if the rates were though not so low as the penny post. We should have to educate the business man up to paying more and the telegraph administrations to charging less, so as to bridge the gap and enable a portion of the mails to be poured through the telegraph wires.

It is impossible to say even to what very limited extent the mail-bags can be depleted by the telegraph; but anything in letters and figures can be transmitted, and even complicated formal printed documents can be filled in by telegraph if a tape-printing telegraph is used. An illustration of this is given in Fig. 3, and the bits of teletype tape pasted all over the printed form will be noticed. A page-printer could not do this.



WAREHOUSE ORDER.

MANCHESTER WAREHOUSE FILL THIS ORDER.
OUR ORDER No. B 68321.
ISSUED AT LONDON.
W.H. No. 726408
BY E.JONES. DATE 10/8 19 24

CHARGE TO J.ROBSON & CO.LTD.
ADDRESS 129 CENTRAL ST
LIVERPOOL.
SHIP TO J.R.CARRON
ADDRESS 45 MARKET ST
IPSWICH.
VIA G.E.RY.
SPECIAL INSTRUCTIONS.
PACK 12 IN A BOX
12 BOXES IN A CASE.

Date Sold 7/8/24	Register No. E 95234	
Salesman POST	Regtr. Cancelled	No. of Sheets 1
Sm.'s Order No.	File No. 324	This Sheet No. 1
Terms 30 DAYS	Price Checked	Billed by
Checked by	Selected by	Bill Checked by
Entered by	Goods Rechkd.	Amount of Bill
Order Rechecked	Packed by	Audited by

ORIGINAL PKGS.	QUANTITY	DOZ. GRO. ETC.	LOT No.	DESCRIPTION.	PRICE EACH.	TOTAL.
	3	GROSS	6 G 13	1 4013 CEILING ROSES		
	1	GROSS	2 C 24	2 4003 S.P. SWITCHES		
				6		
				7		

TELETYPED BY H. WOODALL 7/8/24 10.30 A.M.

RECEIVED AT MANCHESTER	PACKING & ASSEMBLY	BILL OF LADING	BLOCK

FIG. 3.—Printed-form tape telegram.

Signatures, on the other hand, are hopeless in spite of telautographs and copying telegraphs, and telegraphic transmission of pictures and drawings will seldom pay.

There is, in addition, one interesting obstacle in the path of transmission of letters by telegraph, about which more may be heard in the future, and that is "enclosures." Many business letters which could be telegraphed with advantage contain cheques, bills of lading and various other business documents, which cannot be telegraphed. The proportion of business letters, otherwise telegraphable, which must go by post on account of enclosures is not known, but the matter was looked into by a London firm in connection with their departmental correspondence. This firm, with offices in London and works 30 miles away, have a private telephone circuit connecting their London offices with their works. This telephone circuit is overloaded with traffic, and a proposal to superpose a teletype circuit on the telephone circuit proved attractive to them. Not only would the carrying capacity of their private wire be increased, but orders and other correspondence that now reach the factory on the following day would arrive by telegraph by the aid of the teletype in a few minutes, thus saving a day in the case of a factory 30 miles away; and time is money.

Upon investigation, they found that 40 per cent of their correspondence with their factory contained enclosures which could not be telegraphed, leaving 60 per cent that could be handled by the teletype. This is instructive, but not sufficiently generalized to be any guide to the average contents of the mail-bags. The proportion of letters that could be telegraphed is well worth investigation by inducing a number of business firms of various kinds to look into the matter and prepare statistics. Also it is obvious that the proportion of letters that it would pay to telegraph would be still smaller. Many firms could no doubt be induced to prepare statistics on this point also. In this way a fair estimate could be made of the extent to which the new telegraphy may benefit at the expense of the mail-bags.

(11) *The first steps.*—The problem of making a beginning with the new telegraphy deserves a little consideration. It will have to start on a small scale, because administrations cannot be expected to spend hundreds of thousands of pounds to install teletype exchanges in all leading cities, and then spend more money in canvassing for subscribers to the new service. There must be healthy growth from small beginnings. It will probably start very much as the telephone service began. A start has already been made in connecting business firms and banks to the Central Telegraph Office. The Dutch Government has installed a considerable number of teletypes for this purpose, and the British Post Office is beginning to do the same. If this service grows it will lead to a concentrator system, because subscribers' lines will not always be busy, and by means of a concentrator switch the traffic can be handled by a considerably smaller number of teletypes at the Central Telegraph Office than the number of subscribers. It seems reasonable to suppose that this arrangement will gradually extend to switching subscribers direct to the particular circuits over which their telegrams would have to be transmitted. The British Post Office already has teletypes in use on long lines, and "through switching" would appear to be inevitable in the course of time.

Another line of growth has already been indicated in connection with the offer of the Western Union and the Bell Telephone Co. of telegraph typewriter service on the private wires of private firms. These private lines will naturally be linked up in due course, with resulting growth of the new telegraphy.

Part 3.

THE START-STOP PRINTER.

(1) *Various machines and what they must do.*—It remains now to give a general idea of what is meant by the title "Start-Stop Printer." As far as possible details will be avoided, because this paper is being written not for telegraph engineering specialists but for the vast number of people who are mainly concerned about better telegraph service. Before beginning this last section of the paper, however, I may also explain that I have refrained from expressing any opinion about the relative merits of the various machines now on the market or being developed. They are the product of a vast amount of ingenuity and research and practical experience, and time will in due course settle which is the best, or what particular combinations of the ideas materialized in these machines will prove to be the most suitable for various classes of work.

The conditions to be fulfilled by a successful start-stop printing-telegraph may be set out as follows:—

(*a*) It must be a start-stop printer; that is to say, it must start operating as soon as a key is depressed on the keyboard, and it must stop as soon as a letter has been printed.

(*b*) Most of the successful machines have a mechanical distributor and a single recording magnet.

(*c*) It must have the standard typewriter keyboard, with easy touch.

(*d*) It must have a speed of from 40 up to 80 words per minute.

(*e*) It must use the five-unit alphabet.

(*f*) It must be able to work over any distance, from 50 feet to 5 000 miles.

(*g*) The option of tape- or page-printing is desirable.

(*h*) For speeds above 50 words per minute, Western Union experience indicates that typebar machines are best; but good results are being obtained by some of the typewheel printers.

(*i*) It must be simple, compact, strong and durable, and able to print at least 5 million words without an error.

(*j*) It must be able to run for at least one month without attention, apart from the supply of fresh paper and ink.

(*k*) Maintenance must be possible without highly skilled labour.

(*l*) The manufacture must be strictly on the interchangeable mass-production basis, to ensure cheap maintenance, quick repair and moderate prices.

(*m*) It should be possible to stop the printer completely and shut off all power at out-station B from head-station A, and start it again from station A.

(*n*) It would be desirable to have a universal printer which, with comparatively slight modifications, could be used on multiplex circuits, or as a start-stop printer with typewriter keyboard, or with perforated-tape transmission, or as a rapid stock-ticker; but there are grave difficulties in the way of making such a machine.

With the exception of the first-mentioned in the following list (which, after being widely used in America for 15 years, is now being superseded by a more recently developed machine of the same company), the only machines at present on the market which attempt, more or less successfully, to fulfil these conditions are the following:—

Start-Stop Printers.

	Approximate speeds*
(i) Morkrum typewheel page-printer (Blick typewheel), the first of the commercially successful start-stop machines. Page-printer only ..	70 w.p.m.
(ii). Morkrum typewheel teletype; the first start-stop machine to achieve wide success outside the United States. Tape-printer only ..	40 w.p.m.

* w.p.m. = words per minute.

(iii) Western Electric start-stop printer. Page-printer only	60 w.p.m.
(iv) Kleinschmidt direct printer. Tape or page-printer	80 w.p.m.
(v) Siemens and Halske "Pendeltelegraph." Tape-printer only ..	40 w.p.m.
(vi) An improved machine by Siemens and Halske based on Siemens automatic system	80 w.p.m.
(vii) Creed direct printer. Tape- or page-printer	80 w.p.m.
(viii) Morkrum page teletype. Typebar page-printer	65 w.p.m.
(ix) Morkrum model-15 typebar teletype. This is the latest start-stop machine. Tape- or page-printer	80 w.p.m.

(2) *Historical.*—Speaking in a general way, what the Western Union calls the simplex printer is a very old idea, going back to the beginning of telegraphy, and it is an astonishing fact that it is only during the last year or two that real success has been achieved. There have been many pioneers, and scores of simplex printing-telegraph inventions fill the shelves of the patent libraries. They were pioneers, and they all failed for themselves; but not for us, because "by their bones about the wayside we have come to our own." They have guided us on the road, and within the last 2 or 3 years we have arrived.

It might be thought that the complicated automatic and multiplex high-speed printing-telegraphs with their enormous carrying capacities of 100 to 300 words a minute in each direction on one wire, and, in the case of the multiplex, with two to six separate channels each way on one wire, would have developed after the much simpler business-man's printing-telegraph; but the requirements of the business-man's teletype are very severe, as will be realized from the list just given of conditions to be filled by a successful machine of this class. Many beautiful machines have been designed; but for 50 years the Hughes printing-telegraph has been practically the sole one-man machine that would work successfully even in a large telegraph office with skilled attention immediately available, and it is not a start-stop printer. The Hughes would be quite unsuitable as the business-man's teletype for several reasons, the chief objection being that it is a synchronous printing-telegraph. It is also big and clumsy, with a piano instead of a typewriter keyboard, and it requires skilled operation to reach even 30 words a minute, whilst 60 words a minute is far beyond its powers. A girl typist cannot sit down and work it forthwith. The fact that it prints on a tape is not a serious objection, though it is believed that page-printing will be demanded in many cases by the business community. They will want at least the choice of tape- or page-printing to meet their particular needs. What business men require is typewriting at a distance. The need has been known for years, but not the way. Twenty years ago Mr. W. A. Hatfield, one of the engineers formerly employed in the Engineer-in-Chief's Office, G.P.O., repeatedly urged me to make a start-stop printing-telegraph with a direct keyboard; but I was too busy with the Murray automatic and the Murray multiplex printing-telegraphs to attempt any other development work. In any case the conditions of success were not known at that time, and the labours of many men and much capital and years of time were necessary to discover the conditions.

The first really successful machine of this kind was the Morkrum start-stop printer, which was put into commercial service in 1910. It was a typewriter keyboard machine with a typewheel page-printer very similar to the Blickensderfer typewheel typewriter. It came into extensive use in America; but it depended for its operation on a considerable number of magnets and electrical contacts, and it required much maintenance attention. It is therefore being superseded by later Morkrum machines. American as well as French experience appears to indicate that a successful telegraph printer should be, as far as possible, mechanical in its action, and further development in America has gone along these lines.

This resulted in the production of the little typewheel "Teletype," which was put on the market in 1920 by the Morkrum Company and proved highly successful. The teletype is the first machine of the kind that has had a wide sale outside of the United States, and from the date of the established success of this new machine the era of the new telegraphy may be said to have begun.

Kleinschmidt came close on the heels of the successful Morkrum machines, with an extremely clever, direct, keyboard page-printer, very neat and compact in design, which is meeting with considerable success. About the same time the telegraph development engineers of the Western Electric Co. were doing valuable work on the start-stop problem. Their start-stop printer worked well, and amongst other things they designed a most ingenious centrifugal governor for their start-stop printer motor, which is easily the best yet made. The work done in developing arrangements for linking up start-stop printers to channels of multiplex installations has already been referred to. Dr. Louis M. Potts also did extremely ingenious start-stop printer work, especially on the idea of the mechanical distributor and single receiving magnet or relay.

The Western Union and the British Post Office, being telegraph-operating and not manufacturing and development concerns, the Western Union engineers, like the British Post Office engineers, and the engineers of other administrations and operating companies, have had to discharge the important duty of testing and criticizing the machines designed by the various manufacturers and inventors, and it is largely from the conclusions arrived at and the requirements and conditions laid down by the telegraph-operating organizations that the manufacturers and inventors have been guided to commercial success.

I mention this because there is often uninformed criticism of the British Post Office on account of the Post Office engineers not having produced any of these printing-telegraph machines. They have not had time, and it would have been quite outside of their duties to have done so. The modern world is highly specialized, and the production and the operation of machinery are two entirely separate functions. Criticism and valuable practical advice can come very properly from the operating administrations, but the work of development of machinery has to be left to the manufacturing concerns that specialize in that class of work.

German engineers, instead of accepting the conclusions of England, France and America in favour of mechanical operation, have employed automatic and electrical principles with success, and Messrs. Siemens and Halske of Berlin have produced a very interesting machine which they call the "Pendeltelegraph," printing on a tape at a speed of 40 words a minute. They have also developed another start-stop printer based on the Siemens automatic system, with a speed for manual operation of 60 to 70 words a minute, and, for automatic tape transmission, of 80 words a minute. It depends on many electrical contacts, brushes and condensers, devices that are not regarded favourably in the light of English and American experience, but it is stated to work well. Those who are interested will find an illustrated account of it in the *Elektrotechnische Zeitschrift* for 24th July, 1924, by F. Lüschen, entitled "Die Technik der Telegraphie und Telephonie im Weitverkehr." It is very instructive to compare the illustrations of this German machine with those of the Morkrum Company, Kleinschmidt, and Creed, all of which are mechanical. The same article gives an interesting diagram showing the remarkable network of Siemens' automatic printing-telegraph circuits linking up all the leading cities of Germany and Central Europe, and extending to London, Rome, Budapest, Vienna, Warsaw, Riga, Moscow and Kristiania and other Norwegian cities. This extension is due to German influence, and not to any superiority of automatic systems compared with multiplex; and if the forecast in this paper of the future of telegraphy is correct, then the whole of this automatic network will in due course find its way to the scrap-heap, because the multiplex is necessary for splitting up wires into a number of separate channels. Tone-selective methods are a practical alternative under certain conditions; but automatic systems are hopeless for the new telegraphy. Although multiplex are undoubtedly superior to automatic systems, yet even multiplex systems will be much modified by the requirements of the new telegraphy.

More recently others have entered the market, including F. G. Creed. The Creed machine, like all these printers, is most ingenious. It is based on the well-known Creed automatic printer, and it is unique in being a typewheel-typebar machine. The typebars are only $\frac{3}{4}$ inch long, and very high speed is secured in this way. The five-unit alphabet is used, and Mr. Creed is to be congratulated on his conversion from the morse to the five-unit system.

The essentials for success are now known, and from what has just been said it will be seen that healthy competition is springing up, and it is all for the good of civilization that every possible way of carrying out the start-stop idea should be investigated and tried, in order that the best may survive. That is specially desirable because of the very great importance of the start-stop printer.

(3) *Technical features of start-stop printers.*—The first essential of a start-stop printer is that it must start and stop for each letter transmitted and printed. Prefixed to each letter signal is a starting signal, which upon arrival at the receiving station starts the printing mechanism, which makes one revolution, in the course of which the letter is printed, and the machine then stops ready for the next letter. This cycle is repeated for every letter transmitted. (For simplicity, I have disregarded the overlap, as this does not affect the argument.)

A little consideration will show that there must also be a stopping interval to give the machine time to come to rest and return to zero. Hence the start-stop printers, although they employ the five-unit alphabet, are really seven-unit systems. The morse uses eight units per letter. The start-stop printers have therefore a slight advantage over the morse key of $12\frac{1}{2}$ per cent so far as the telegraph line is concerned.

The only alternative to starting and stopping for each letter is for the sending mechanism at station A and the receiving mechanism at station B to run continuously. For simplicity let us consider the Hughes printing-telegraph, which runs in this way. At each end of the telegraph line there is a typewheel, and these two typewheels have to run synchronously, that is to say, the same letters on each typewheel must point to the 12 o'clock position at the same instant, and mechanism has to be provided for correcting any lapse from synchronism. It is only while signals are being transmitted over the line that the synchronism of the Hughes is maintained. When transmission stops the Hughes falls out of synchronism, and synchronism would have to be re-established for each new connection before messages could be transmitted. In any case, to keep a number of Hughes circuits all tuned to the same speed would not be easy with the present governing mechanism. Also, in the event of no one being present at the receiving station there would be no certainty that synchronism had been established. Hence a printing-telegraph depending on continuous rotation, and therefore on synchronism, could not be used in a printing-telegraph exchange. The start-stop principle is essential. In any case, for reasons already mentioned, the Hughes would be out of the question for such a purpose.

The start-stop printer comes to rest between each letter or during intervals between messages, and it can thus be switched easily from one circuit to another. The only condition is that there shall be approximately a standard speed for all the teletypes or other start-stop printers. About the subject of speed more will be said presently. It is true that even the "start-stop" machines depend on synchronism, but only during the one revolution that prints a letter, and it is very easy to preserve synchronism for such a short period as $\frac{1}{4}$ second or even less, and in this fact lies one of the great advantages of the "start-stop" machines for exchange work.

The next point about which some explanation is desirable is the mechanical distributor and single recording magnet of the successful start-stop printer. The Hughes is a single-magnet printer, but it does not have a mechanical distributor. In the Hughes the channel is an electrical transmitting distributor only, and [illegible] out at station A an electrical impulse at the right moment for printing correctly at station B, the typewheel at station B revolving in synchronism with the typewheel at station A. The typewheels are the distributors, and in the Hughes there is no mechanical distributor in any sense corresponding to the mechanical receiving distributor of the modern start-stop printers.

(4) *Electrical and mechanical distributors.*—The value of the mechanical receiving distributor will be best understood by considering an electrical distributor and a printer in schematic form as shown in Fig. 4.

The receiving line-relay is shown at 1; 2 is the electrical start-stop distributor, the brush arm 3 being kept from revolving by the pawl 4. When a starting signal arrives in relay 1, it closes the contact at 5, and local current then passes from the battery 6, through ring 7, brush arm 3, starting contact 8, starting magnet 9, and back through contact 5 to the battery. The magnet 9 attracts the armature pawl 4, releasing the brush arm 3, which starts revolving to the right, the brushes making successive contact with the segments 10 to 14, which are connected to the five selecting magnets 15 to 19. Depending on whether the contact at 5 is open or closed by a line signal when the brush makes successive contact with the segments 10 to 14, impulses or no impulses will pass through one or more of the magnets 15 to 19, and one or more of the five armature pawls 20 will be attracted, and will release their corresponding selector plates 21. In this way a special permutation group of slots in the selector plates, corresponding to the letter signal transmitted, will be aligned and a latch, in this case corresponding to the letter S, will be selected and, by suitable mechanism, will print the letter S. The printing action also restores the selector plates to zero position, and the pawl 4, catching the brush arm 3, stops the machine until another starting signal, followed by a letter-signal group, arrives.

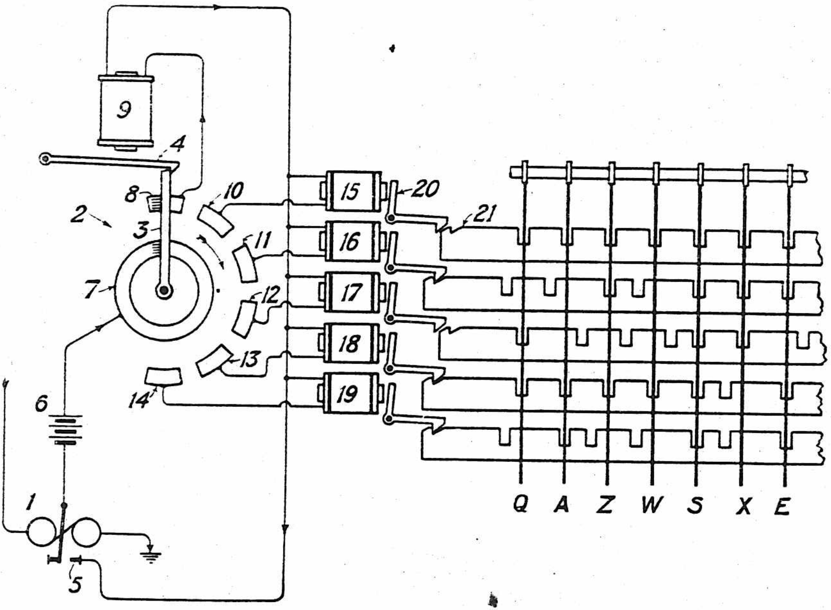


FIG. 4.—Diagram of principle of five-magnet printer and an electric distributor.

In electric distributors the chief difficulty is the contact brushes, which wear badly and require frequent attention. In the case of multiplex distributors the traffic and the carrying capacity are very great and the cost of daily attention to the brushes is trifling compared with the results achieved; but in the case of the start-stop printers the position is far less favourable. Such machines are necessarily scattered over a considerable area, often miles apart, and it would consume too much time and wages to send a man daily to attend to the brushes. The maintenance attention should not exceed once a week and preferably once a fortnight, or even once a month. Compared with an electric distributor using brushes, the mechanical distributor is a great step forward. It does not require attention for months at a time and even then it only needs a drop of oil, which can be given by anybody. With the exception of one magnet to record the signals coming over the telegraph line, the receiving and printing mechanism of the modern start-stop printer becomes in this way entirely mechanical. Another important advantage of the mechanical distributor is the fact that, on lines not sufficiently long or difficult to require a relay, a start-stop printer equipped with a mechanical distributor can be worked by alternating current and without any direct current. An alternating-current motor to drive the machine is all that is necessary, in addition to the signal magnet to record the line signals. No local direct current is needed.

The principle of the mechanical receiving distributor is the same in all the successful start-stop printers so far produced, and it will be readily understood from the schematic illustration of one form of mechanical distributor, in Fig. 5, and the following description :—

The signals arrive in the single magnet 1, which corresponds to a morse sounder. The first signal is the starting impulse and causes the magnet to attract its armature 2. This trips the pawl 3, and also by the link 4 it trips pawl 5. This throws in a clutch 6, which couples the constantly rotating power shaft 7 with the start-stop shaft 8. This carries the cam 9, and by means of five-to-one gearing it also operates cam 10. Cam 9 oscillates the lever 11 pivoted at 12. Lever 11 carries a rod 13, which is pushed by the rod 14 along in front of the five selector plates 21 (ends only shown, but they are the same as in Fig. 4), the rod 14 being moved by the cam 10. The rod 13 reciprocates regularly as shown by the arrow 15, under the control of the rod 11, which is kept oscillating by the cam 9. If, however, there is no operating or marking signal in the line, the magnet 1 will cease to attract its armature 2 and the pawl 3 will catch and retain the rod 11, thus preventing the rod 13 from striking the selector plate opposite which it is passing at the time of no signal. Assuming that there is no signal operating the magnet 1 when the rod 13 is opposite selector plate 1, and that there is a signal when the rod is opposite selector plates 2 and 3, no signal when the rod is opposite plate 4 and a signal when opposite 5; then the selector plates will be pushed into the particular permutation shown at 16. Immediately afterwards, a tooth 17 on the rod 14 strikes the end of the lever 18, causing it to trip the printing mechanism into action, and a letter corresponding to the permutation set up in the selector plates will be printed. The clutch 6 is disengaged automatically by the cam surface 19 striking the plate 20, and the released half of the clutch is then caught once more by the pawl 5, ready for the starting impulse of the next letter signal.

On the other hand there has been a sort of rivalry between the mechanical distributor and tungsten contacts. These have proved wonderfully goo electric distributors, and run for months at a without attention. As a matter of fact, tung contacts opened and closed by spirally arranged on a transmitting spindle are employed in the Mork teletype for the transmission of signals, and experi shows that they run almost indefinitely without atte tion. It will be seen, therefore, that there is a goo deal of variety possible in the design and manufactur of start-stop printers. The mechanical distribu however, appears to be cheaper and simpler and mo compact than electric contacts with five selecti magnets, and the Morkrum teletypes, the Kleinschmi and the Creed start-stop machines all use the mechani distributor.

The demand for high speed, at least 60 words minute, has been a stumbling block. Typewh machines like the Hughes and Baudot appear to reach their commercial working limit at about 40 words minute. Beyond that speed the cost of mainte rises rapidly, and American experience indicates th for speeds much beyond 40 words a minute the typ principle is the best. The typewheel machine, howe has the advantage of great simplicity of pri mechanism, and in one or two cases good results being obtained at higher speeds. There is a si typewheel instead of 26 typebars and parts, and th is a simple little ink-roller instead of the necess complicated ink-ribbon feed with automatic re The demand for speed, however, is insistent, and Western Union, as the result of great experience, h decided definitely in favour of the typebar machi The Morkrum model-15 teletype is one reply to t demand. This machine has an extremely ingen mechanical distributor and, having typebars, it wo well at 75 words a minute and has been tested up to words a minute. These high speeds are quite pr ticable for tape-printing, but, in the case of page-pri time has to be allowed for the carriage to run back

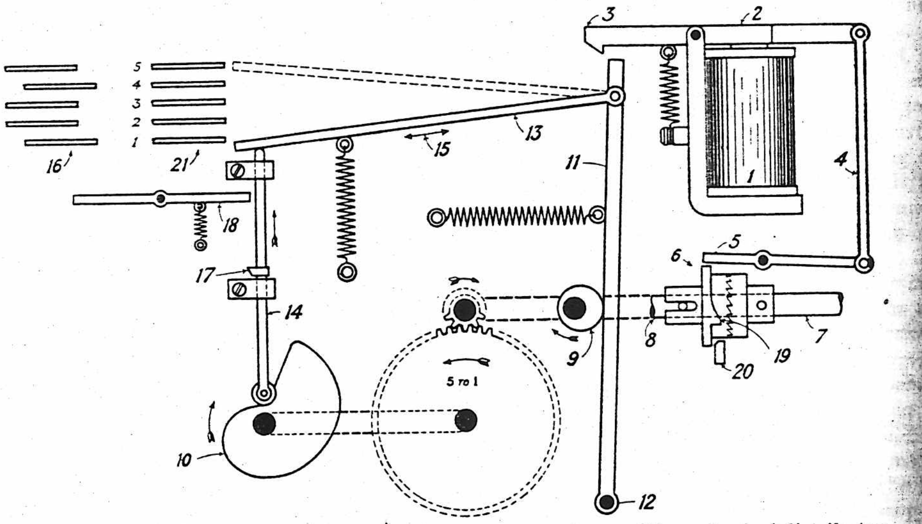


FIG. 5.—Diagram of principle of single-magnet start-stop printer with mechanical distributor.

at 75 or 80 words a minute the time of at least three letter signals must be allowed for the return of the carriage. This is not a serious drawback, but it is a deduction from the high speed in the case of a page-printer. The Kleinschmidt direct keyboard printer is another answer to this demand for a rapid typebar typewriter-keyboard start-stop printer.

(5) *Curved code-bars.*—In the Morkrum model-15 teletype there are two, amongst other, interesting features demanding notice, namely, the curved code-bars and the combined striker-bar and lifting-bar. These two devices effect a surprising simplification in a typebar printer. I devised these two features and patented them in Great Britain in September 1922 (British patent 206975), only to find, on writing to the Morkrum Company, that they had hit upon the same ideas independently. We afterwards found that a French inventor named Eglin had patented a printer employing the curved code-bar idea in December 1912. He did not use the combined striker-bar and lifting-bar, and his selecting mechanism is rather complicated and apparently not very practical, and his printer is not provided with a distributor. It is for multiplex working with five selecting magnets, and it is not a start-stop printer like the machines referred to in this paper.

In Fig. 6, A and B are the second and third diagrams in my British patent 206975. The Morkrum Company's solution of the problem is substantially the same. In A the curved code-bars are shown in section at 1; 2 is a typebar; 3 combines in one piece the selector latch, printing hook and connecting piece to the typebar, and 4 is the combined striker-bar and lifting-bar. At the right moment this bar moves forward and back as shown by the double arrow 5. When moving to the right it no longer supports the latches 3, which then rest on the curved code-bars. It is understood that there are 27 of these latches, corresponding to the 27 typebars. For any given permutation of the curved selector plates shown at B only one latch 3 will be selected and will be free to fall into the aligned group of slots, and the hook 6 will then engage with the striker-bar 4, and further motion of the striker-bar to the right will cause the typebar to rise and print. When the bar 4 moves to the left, the wedge portion at 7 lifts all the latches off the code-bars, which are then free to be set into a new permutation by the next signal transmitted over the line.

At B five magnets of the electrical distributor plan are shown controlling the code-bars, but the principle of the mechanical receiving distributor with a single magnet is readily applicable in the case of the curved code-bars, and it has been applied by the Morkrum Company in their model-15 teletype in a highly ingenious manner.

I have described this curved code-bar machine at some length because of the remarkable simplification obtained by the arrangement shown at A together with the semicircular code-bars shown at B. The importance of this simplification lies in the necessity for high speed, at least 60 words a minute, for start-stop printers. For such speeds typebar printers appear to be best; but typebar printers, owing to their complexity, have hitherto been very costly. The simplification resulting from the devices described above is therefore a distinct step forward, and in this respect there does not seem to be room for further improvement. The ink-ribbon mechanism of typebar printers is their one remaining drawback. It is more complicated than is desirable, and compares unfavourably in this respect with the simple ink-roller of the typewheel machines. On the other hand, I am informed by the Western Union that as the result of 15 years' experience they found ink-rolls a source of great trouble and worry. They have found ink-ribbons far less troublesome and also cheaper than ink-rolls. This appears to be another case in which the complexity of the "Rolls-Royce" is preferable to the simplicity of the wheelbarrow.

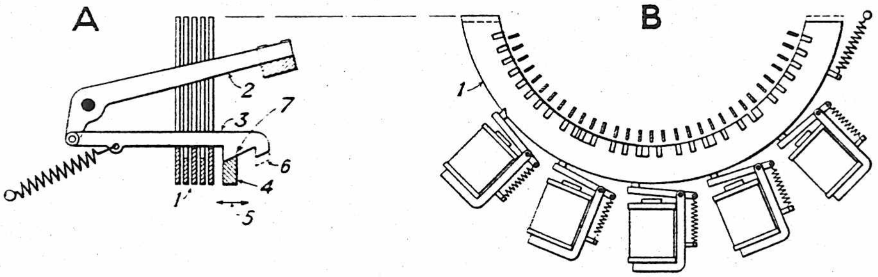


FIG. 6.—Diagram of curved code-bar printer.

(6) *Standard speed and tape- or page-printing.*—I have now completed the story of the new telegraphy and its machinery, and there remain only a few final words about one or two points that will cause difficulties if agreement is not reached in regard to them. They correspond in a curious way to the old problem of the standard railway gauge, which still gives the world some trouble.

The first and most important point is the question of a standard speed. Clearly the start-stop printers must run at approximately the same speed everywhere if there is going to be free intercommunication as on the telephone. In the case of the telephone this question of speed does not arise, because the speed is determined by the human voice, and we all talk at about the same speed (100 to 200 words a minute). In the case of printing-telegraphs the allowable speed variation is small. Fortunately, so far as the machinery is concerned, this requirement is easily fulfilled by suitable governing mechanism, and tuning forks and the stroboscopic effect enable speeds everywhere to be regulated with great accuracy in less than a minute. The difficulty arises from other considerations.

The lower the speed the greater is the margin of security on the telegraph line; but the higher the speed the more words can be telegraphed within the time limit. The lower the speed the greater is the durability of the apparatus and the lower the maintenance cost, and the higher the speed the lower are the capital cost and the maintenance cost of the wire plant in proportion to the work done. The lower the speed the greater is the accuracy on the part of the human transmitter of messages; but the higher the speed the more business can be done and the more information and instructions can be transmitted within a given time. For circuits superposed on telephone lines, low speeds, say 40 words a minute, are desirable, while on ordinary telegraph lines higher speeds, say 60 words a minute, have advantages.

As start-stop printers or teletypes will have to be linked up with channels of the multiplex, the speed of the teletypes will be controlled by the speed of the multiplex, a matter quite easily arranged. Certainly it would not be practicable to alter the speed of big multiplex installations and networks, and quite impossible to give different speeds on different channels of the multiplex. Also the speeds of various multiplex installations differ in accordance with the line conditions. Certain fixed speeds for the multiplex are necessary, and a convenient solution of the intercommunication problem seems to be speed-change gears on the teletypes. The question does not arise in the case of carrier-current or tone-selective channels, except that the start-stop printer speeds between two correspondents must be the same.

There is still another question. What is the best working speed for a typist? There is complete disagreement everywhere on that point, and the rate advocated ranges from 40 to 80 words a minute. Apparently 60 words a minute may be accepted as the happy mean; but on long and difficult telegraph lines the speed of 40 words a minute gives a wider and safer margin for working. Evidently start-stop printers will have to be provided with three-speed or even four-speed gears like a motor-car, say 40, 60 and 80 words a minute. Two subscribers, on being connected at 40 words a minute, could agree on increased speed and gear up accordingly by moving a lever on each teletype. Even speed gears would necessitate agreement about the three or four speeds to be provided. These would have to be standard; but it would be much easier to agree on three or four speeds than on one. The question will have to be decided largely by experience, and fortunately in America there is a splendid field for experimental settlement of the problem. Later on, so far as Europe is concerned, there will have to be international agreement about start-stop printer speeds, and such agreement will have to include all leading nations because, in the course of time, teletype exchange and multiplex working will certainly extend through ocean cables and possibly by wireless across the great oceans.

The second and only other serious controversial point in connection with the new telegraphy is the question of tape- or page-printing. Tape-printing is considerably simpler than page-printing. It is therefore cheaper and the maintenance cost is lower. Also, for the distribution of market prices, weather reports and news to farmers and other private subscribers, tape-printing would appear to be the best arrangement. Using pre-gummed tape like postage stamps, the printed tape can be readily attached to sheets of paper. In the case of the Western Union Telegraph Co., after having about 2 000 page-printers in use all over the United States for the past 8 or 9 years, the company has decided to change over to tape-printing, and has already ordered over 800 tape-printers to replace page-printers. In this case, however, there are special reasons in favour of tape-printing, which do not apply in the case of Government administrations. There is sharp competition between the Western Union and the Postal Telegraph companies, and the Western Union prefers not to send out messages with visible corrections. Consequently, messages containing errors have to be retransmitted. This occasions loss of time and labour, which is avoided with tape-printing, as errors in tape can be cut out so as not to show in the finished message. There is also a considerable percentage loss of time in transmitting the signals to run the typewriter carriage back and turn up to a new line, and at the end of messages time must be given to the printer attendant to turn up to a new message form for printing the next telegram. In the case of news messages, on the other hand, page-printing has great advantages, because it saves time and labour, and it is doubtful if large firms with much telegraph traffic would accept tape-printing on their teletypes. They are accustomed to typewriters and they will demand typewriter service. That is to say, they will probably demand page-printing.

It is clear that there will be trouble if one subscriber has a tape-teletype and another a page-teletype. As it happens, a message containing page-printing signals will print all right on a tape-printer, but a message transmitted for a tape-printer without page signals will not print on a page-printer. A tape-printer typist could send the page-printing signals even on a tape-printer keyboard, but the situation is not as clear as could be desired. Of course as long as the Western Union and the Bell Telephone Co. confine themselves to their present plan of selling telegraph typewriter service only to business firms for use on their own private wires within their own organizations, the problem of tape- or page-printing will not arise. Each firm can choose tape- or page-printing; but when the inevitable linking up of such private-wire systems through teletype exchange takes place, the tape- or page-printing problem will require consideration. One point to be borne in mind is that when start-stop printers are being used in great numbers, prices will come down, and it will then be practicable for firms to have several tape-printers and several page-printers, thus giving the option of either tape- or page-printing. For certain classes of work page-printing is impossible. Fig. 3 is an illustration of what tape-printing can do and what page-printing cannot do. There is certainly much to be said for tape-printing in connection with the new telegraphy, but, on the other hand, page-printing saves time and labour when there is much traffic and it gives nicer-looking results.

(7) *A universal printer.*—Another point for consideration is whether it is not possible to have a universal printer available for all telegraph service. This, I understand, is the idea at the back of the mind of the Western Union, and there is much to be said in its favour. It certainly would be desirable to have a universal printer that would do for multiplex circuits, for start-stop circuits and also for stock-ticker service; and I, and no doubt others, have had our thoughts directed to this ideal for a long time past. Such a printer would be the real Ford car of printing telegraphy. A printer absolutely identical for all services is evidently impossible, but the modifications required for each class of work are not serious. The five-unit alphabet being used, all the essential parts of the machine would be the same for each service. This would allow of production in quantity, with corresponding reduction in cost and corresponding extension of the field of telegraph service. The answer of the Morkrum Company to this requirement is the new Morkrum model-15 teletype which will work up to 80 words a minute. It is tape-printing or page-printing as desired. It is a start-stop printer with a direct-transmitting typewriter keyboard, or it can be used with a keyboard perforator and automatic tape transmission. By substituting five selecting magnets it can be used on multiplex circuits. Apparently there is nothing to prevent any of the start-stop machines being so constructed as to be available with suitable modifications for these various services, and it will be a question for time and the telegraph administrations to determine which is the best.

Hitherto stock and news service has been confined to city limits on account of the step-by-step principle of signalling employed. The use of a modern start-stop printer for the distribution of news and market prices will sweep away the city limitations of stock-ticker service, and distribution will become nation-wide. The five-unit alphabet being used, there will be no bar to universal ticker service, including distribution to distant centres over channels of the multiplex. Prices are already being broadcast by wireless; but the arrangement is unsatisfactory. Only a few leading prices can be given, because to listen to a whole stock-list for the day by wireless would be unendurable. Also, broadcasting suffers from all the disadvantages of the telephone. It is a voice and nothing more. There is no record and there must be fixed times for listening, and there is the risk of error of the telephone plus the risk of error from atmospherics or static. The printing-telegraph for news is the only way.

In America, for instance, there is already a very fine ticker service (and so there is also in this country); but with the new machinery it will certainly develop to a marvellous extent, covering the whole of the United States and Canada, and serving not only stockbrokers and produce dealers but also farmers and private homes. Every well-to-do family will have its ticker service superposed on its telephone line for news and its radio set for amusement. The family will turn on the music and read the news.

(8) *Prices.*—At the back of all the wonderful possibilities outlined in this paper is the question of cost. Will it pay? That depends on the value of the service rendered. Printing-telegraphs have already proved extremely valuable to telegraph administrations, and there is acknowledgment of that fact in the annual report of the Western Union Telegraph Co. for the year 1920. In that report it was stated that, since 1915, multiplex printing-telegraph apparatus had been installed costing approximately 2½ million dollars, saving the expenditure of $16 585 000 on wire plant, which otherwise would have been required. Nothing was said in the report about the labour-saving, which is known to be substantial, and during the four years that have passed since that report was issued there must have been still further expenditure and resulting economies both on lines and labour, bringing the total saving to the Western Union up to somewhere about 4 million pounds sterling. There is no doubt that printing-telegraphy is very profitable to the telegraph administrations. It is also very profitable to newspapers and news-distributing organizations, and the stock-ticker service manages to pay its way in most countries. This paper also will have been written in vain if the start-stop printers do not render profitable service on a large scale; but there is a law of diminishing returns in such cases, and the margin of cultivation may be taken as the employment of the start-stop ticker in the home. For stock and produce brokers, merchants and farmers, the teletype will undoubtedly render commercially valuable service for which it will be worth paying a substantial price; but in the home the ticker, like radio apparatus, must be regarded as a luxury, and the extent of this particular market will depend on low prices and cheap maintenance. These are also important considerations in the more profitable markets already referred to. In short, everything depends on the price.

Reference has already been made to the unprofitable years of development work and the heavy expenditure incurred in producing these simple-looking little machines, the start-stop printers. Naturally the manufacturers have to get their money back with a profit or go out of business, and the present selling price of these machines is therefore about £90 to £180, depending on the amount of apparatus and kind of service required. Not only has the production been expensive, but the cost of selling is high. The "education of the market" takes much time and money. However, with the increase in the numbers sold, the cost of selling as well as the cost of making will fall, and when the stage of mass production by tens of thousands is reached and orders run into thousands at a time, the prices will fall probably to about twice the cost of a typewriter of the better class. If the total sales ultimately go into the millions like typewriters, it is possible that the prices will come down to the typewriter level, and they will then find their way into the more prosperous homes, just as the portable typewriters are doing. Mr. G. M. Yorke, Vice-President in Charge of Engineering, Western Union Telegraph Company, New York, writing to me on the 1st May, 1924, said:—

"We agree with you that one difficulty about the printing-telegraph business is the cost of the machines. We hope to get American manufacturers on a Ford-car basis within the next 5 or 6 years. However, on the whole, our regrets in connection with our printing-telegraph developments are small."

In conclusion, it may be of interest to add that official steps are already being taken to investigate the new telegraphy thoroughly under experimental conditions, and, if the results are promising, it is probable that some form of practical trial will be made. Fortunately, the new telegraphy lends itself readily to experimental laboratory trials with a couple of small 10-line switchboards and a dozen start-stop printers, and I anticipate that, as the result of this paper, experiments of this kind will before long be instituted by all the leading telegraph administrations.

DISCUSSION BEFORE THE INSTITUTION, 18 DECEMBER, 1924.

Colonel T. F. Purves: Although I am not at liberty to speak very freely on this subject, I should not like it to be thought that the Post Office does not feel the keenest interest in the proposals put forward by the author. I might say, indeed, that any suggestion from him on a subject of this sort would always be treated with the greatest respect, and, as he knows, steps are already being taken in a practical way with a view to giving his proposed method of communication a practical trial under the most favourable conditions that we are likely to find in this country. In that way I hope that before very long we shall have a certain amount of actual evidence to show to what extent the British public is prepared to support the proposal to provide a printing-telegraph switching system for personal use by subscribers. I rather emphasize the words "British public" from a point of view that will appeal to those who have had occasion to study the viewpoints of different nations, or to compare their various degrees of responsiveness to publicity and advertisement, either private or governmental. I quite agree with the author that the great weakness of the telegraphs is lack of what he calls terminal facilities. On the engineering side his proposals involve many problems that will require much study in their economic realization, but in themselves they present no serious difficulties. The author describes enthusiastically and quite legitimately the large numbers of channels of communication that can now be obtained from a single telegraph or telephone line by modern methods of multiplexing or superposition. These methods have gone very far and will no doubt go further still in practice, but I should like to mention that another factor is also at work inasmuch as the scientific study of line conditions and construction, and the application of repeaters, is reducing the cost of providing lines in great numbers between important traffic centres. The annual costs associated with multiplex telegraph and telephone apparatus are fairly high, and the point at which it is economical to provide additional lines and use simple self-contained apparatus is a shifting one. There may be some reaction in favour of not demanding from the line all the effective signalling speed of which it is capable, especially in connection with switching systems which are apt to become so complex in themselves that the additional complexities of multiplexed channels are formidable. The author is quite entitled to claim, as he does, that the telegraph can transmit intelligence with a far smaller number of line impulses than the telephone, but I think that his arguments on pages 248 and 249—based on his Fig. 1—go rather too far. The telephone has to transmit over its line a frequency as high as 2 500 per second in order to be properly intelligible, and the equivalent telegraph speed of that line, at 7 impulses per letter, is 6 850 words per minute. It seems too good to be true! I think that the author is overlooking one thing which entirely alters the practical aspect of the comparison, and that is the respective efficiencies of the receiving apparatus—in one case a telegraph receiving apparatus, and in the other case the human ear. The power of the human ear to correct distortion and to transmit intelligible signals to the brain is nothing short of marvellous, whereas only a slight amount of distortion will completely upset a printing-telegraph receiver and convert its record into a mass of meaningless symbols. It is generally admitted that the telephone is not well adapted for the transmission of written messages and figures, but that disadvantage applies rather to its use by the public than to its use by practised experts who are accustomed to work together. It is generally a slow and painful business to dictate a phonogram, but I have listened to the transmission of news at a very rapid conversational speed between London and Paris on frequent occasions, practically without any hitches or any requests for repetition, and being taken down, of course, in shorthand at the other end. I have been, too, in the offices of busy stockbrokers who have been transacting important business over the telephone and receiving figures and fractions at high speed, and the work has been going on with perfect facility and no sign of any strain. I feel that one must be fair to the telephone in this respect. I think also that the author is a little less than fair to the possibilities of broadcasting market news by wireless; and I would suggest that it is not very safe policy for a printing-telegraph engineer to make light of such possibilities. I welcome the paper as a notable contribution towards the very desirable end of revivifying the telegraph service, which, both in this country and elsewhere, has been in danger of sinking into quite undeserved disrepute. As the author remarks, the need for a simple printing instrument for the use of renters of private wires between their offices and public telegraph offices has been felt for many years and is now at last The same instrument is excellently suited for a intercommunication system, if such a system is wanted by the public. The “ start-stop ” feature, which has so many advantages, is perhaps not ideal for a switching system to be used outside of office hours. I question whether many people would care to transmit important confidential messages without having received an intimation that they had really been placed in communication with the office they required, and without any acknowledgment of receipt. I rather think that the fear of having got connected to a wrong number, and of giving some useful information to a competing firm, would be a decided deterrent to the adoption of such a system. I am not impressed either with the suitability of the printing-telegraph for sending and receiving service switching instructions. In spite of the attractions of an entirely separate telegraph switching system with multiplexed lines, I think it would be well not to rule out the idea of combining it with the general telephone system, which already provides a great and ever-growing network of switching channels running everywhere. The new system of voice-frequency telegraphy makes it possible for the telegraph to be worked on any circuit that will carry a telephone conversation—with all its equipment of manual or automatic switchboards, transformers, loading coils and speech relays—and the facility of switching at will from the telephone instrument to the printing-telegraph, and vice versa, must prove a great asset. The telegraph instrument must, of course, be suitably designed and equipped from the signalling standpoint. Its line current must be kept very low in order to avoid interference with the telephone system, but that is a condition which must apply in any event, as telephone and telegraph conductors are now inextricably united in the new underground cable system of the country. I might remark also that the author's financial calculations as to remunerative rates, etc., refer to conditions which seem to approach a good deal closer to the ideal, in the matter of steady and continuously sustained traffic, than is ever likely to be experienced. As regards the automatic switching of telegraph circuits, it may interest the author to know that a good many years ago the question of converting the London intercommunication system to automatic switching was under consideration, and a system was designed (on paper) which would have met all the conditions. It was not proceeded with because it was then becoming obvious that the competition of the telephone would, in a comparatively short term of years, do away with the need for maintaining a telegraph switching system for the offices of the London area.

Mr. J. Newlands : The author says that the telegraphs as we know them in this country are slow, costly and inefficient. From the commencement (in about 1846) the telegraphs grew like a tree and the different branches had to be interconnected. It is still much too like a tree ; there are far too many different transmitting points, and that is the real cause of this slowness and costliness. In the early days different kinds of apparatus were taken over from different companies, many of which have entirely disappeared. The single-needle system has practically gone out of the Post Office service, as also have the acoustic needle, the A.B.C. and Bright's bell. We have here a paper the author of which tells us candidly that he thinks the day has come when the sounder also ought to go—that it has served its day and generation, and has become more or less obsolete. I am inclined to agree with him, but we must remember that while the sounder is very cheap and easily produced in large numbers, the present cost of the teletype is almost prohibitive. I quite agree with the author that there are too many circuits, and that the terminal facilities are at fault. What is the reason ? The apparatus is far too slow ; the operators were too slow ; many of them are still too slow. I tried for many years to improve the rate of working by what is known as the “ average ” system ; but my efforts fade into insignificance compared with the author's sweeping recommendation to “ scrap the lot.” As the telegraph business grew, the number of offices on a circuit had to be reduced to 3, 4 or 5. There are very few circuits that I can recall which have more than 5. Now, if the teletype is so constructed that not 5 but twice or three times 5 offices doing a moderate amount of business can be put on a telegraph circuit, then its increased rate of working will enable a great many of the existing circuits to be grouped on to one teletype, and in that way it will effect economies at transmitting offices. I think that is possible. The telegraph distribution system of this country will have to be totally revised if the teletype is to have a really good chance. If the sounder is to go, then I would suggest that the transmitting offices should be roughly something as follows : London (with a wide area), Bristol, Norwich, Birmingham, Nottingham, Sheffield, Leeds, Manchester, Liverpool, Glasgow, Edinburgh, Aberdeen, Belfast, Dublin and Cork ; that these larger places should be freely interconnected, and that they should reach all the area around them. This would, I believe, greatly reduce the number of transmissions to and from rural localities, probably to an average of two per message. The author, in endeavouring to show how people sitting in their offices could be connected all over the world, refers to the question of a “ bottle-neck ” at the cable ends. Now, one of my former operators, Mr. J. B. Heggerty, suggested a reversion to the old Umschalter switch such as is now used in Belgium. He proposed a system of joining through each telegraph office “ direct ” to any other office it required, each in turn. That is perhaps suitable in a country such as Belgium, where Antwerp and Brussels are within easy reach of the whole system, but Mr. Heggerty's scheme was turned down for the reason that it is impossible to be continuously altering the length of a circuit. The author proposes to switch through direct up to 5 000 miles. The faults which are inherent in our telegraph system would, I think, condemn such a scheme as that ; there would be “ bottle-necks ” all over the country. With regard to a teletype exchange system for London, I do not think there is a real case for that at all. The author admits that the telephone is much better suited for such a populous city, where there is not a great deal of telegraph communication except between the head office and a business firm's works. On the other hand, I think that if there is an effective demand in the country for a teletype exchange similar to the telephone exchange, it ought to be attached, not to the telephone system, but to the chief or central telegraph office, which, in connection with its phonogram room, should have certain wires put apart. Let me take for illustration the most central town in England. If there is an effective demand on the part of business men or stockbrokers or banks for a teletype exchange from London to Birmingham, I think the department should put one good experimental wire at the disposal of the Central Telegraph Office and see what it can obtain in the way of business. I see great possibilities in the way of the simplification of telegraphy by the adoption of the teletype for speeding up the telegraphs. I see the prospect of great economies on the part of the administration, especially if the cost of the teletype can be lowered, and, if the teletype apparatus can be made in bulk in this country and can be placed at the command of the Post Office, I think that it will make very rapid progress indeed.

Mr. E. H. Shaughnessy: On page 254 the author says: " The circuit facilities will be still greater when half a dozen wireless beams work across the Atlantic each at 300 words a minute." I think that this is even more than wireless engineers will prophesy with any degree of confidence; but on the next page I read that: " Even if this were possible, there are the inaccuracy of wireless, interference troubles and atmospherics, and there is no way of answering back." So that although he is looking forward to wireless to help him, at the same time he says that wireless is no good. When discussing costs, the author speaks of the rapidity with which this scheme will enable telegraphy to be carried on, and on page 260 he says: " A great advantage that the telegraph possesses over the telephone is that a telegraph message can be stored up at any point where there may be a ' bottle-neck,' until its turn comes for transmission." This indicates that a fault of the present telegraph delay owing to bottle-necks is even turned into an advantage in this method. The price of the teletype, or any form of start-stop printer, viz. £90 to £180 as given by the author, must undoubtedly be reduced if the telegraph is to compete with the telephone. It will be a very serious position if a million subscribers are obtained, in each of whose offices an instrument costing £100 will have to be installed. First of all this would involve a capital expenditure of £100 000 000 for instruments alone, and I think that is the sort of development visualized by the author in 25 years' time.

Mr. J. E. Kingsbury: Reading the paper from the telephone point of view I have some doubt whether it will be possible to introduce his method in the way the author suggests. For the purpose of analogy I have compared the conditions with railway traffic, of which there are two kinds, passenger and goods. The passenger traffic we may consider as being of the first importance, and for the purposes of analogy we may call speech the passenger traffic and the written word the goods traffic. Now terminal facilities for goods traffic are usually regarded as a very expensive item, and only to be taken advantage of by those who have a great quantity of goods to despatch. Terminal facilities from the point of view of the telegraph were, we must remember, suggested even earlier than the author records in his paper. Simply as a matter of history I should like to remind him that the first exchange system was that patented by Dumont in 1851. It was there suggested that the telegraph line should be taken into the house or the office of the sender and the receiver. Now if the most is to be made of long-distance facilities the goods must be collected in detail, forwarded in bulk and distributed in detail. In a sense that is what is done by the telegraph of to-day. The author suggests that better results can be obtained only by forwarding direct from the sender to the receiver. To my mind that is all a question of cost and convenience. In the case of a line capable of conveying the number of vibrations shown in Fig. 1 (which are adapted to the machines at either end as at present used, but depend for the economic use of the line telegraphically on the multiplication of a number of machines utilized by different people), economy is dependent upon the simultaneous requirements of a number of people to use that line—and in practice, of course, the requirements will not be simultaneous. The collection of goods at a central depot, from whence they would be forwarded in bulk to some other distributing centre, would enable more traffic to be obtained from the line itself than would the general provision of terminal facilities. On the other hand, there can be no question of the great advantage to certain users of direct telegraphic communication such as the author proposes, but I would suggest that the system should be tried in the first instance in an independent teletype exchange. I think that if the teletype printer were added to the existing telephone system, the telephone subscriber would strongly object to find that his line, which was adapted for passenger service, was being monopolized for goods to the detriment of his passenger service. Again, the cost of the teletype appears to be so high as to justify the further increase necessary to give it a separate line. Therefore I think that the author should amend his estimates by making provision for a separate teletype exchange in order to give the system a fair trial.

Mr. T. B. Johnson: I agree with the author that there is a field for the extension of the telegraph in work for which it is more suitable than the telephone, and I say that in spite of the fact that I am an enthusiastic advocate of the development of telephony and especially automatic telephony. The crux of the question is to what extent the business man really wants a written record. It is exceedingly creditable that transactions of such importance as are carried on at every moment of the day, depending entirely on the word of the men at the ends of the line, are honoured and carried out, but still there is some need for a written record. Whether the start-stop printers would satisfy the requirements I am unable to say, but if they will—and the author states that they can be transferred from a short to a long line—then I believe that there is a field for them. Broadly speaking, material is cheap and labour is dear; and if we can save labour every day the cost of these machines, which will inevitably fall considerably as their extends, will not be a really serious bar. At the present time there is far too much writing down of telegrams in different places. Take Leeds and Bradford, for instance, each of which cities has some smaller telegraph offices connected with it. A telegram from a place near Bradford has to be written down in Bradford; it has to be transmitted in turn to Leeds and to the office near Leeds. Teletype exchanges at these two cities would save a good deal of transmission, and each transmission in addition to the cost also involves an additional risk of error. The author, in his estimates, has not taken sufficient account of the cost of labour at the switching centres. In practice it would be found that the cost of switching of telegrams would be much more than he anticipated, and telephone engineers will agree with me that the cost of switching, no matter what attemps are made to cheapen it, is always appreciable. It would, however, be much less than the present cost of writing down and re-transmitting. I do not agree with the author that farmers will take much advantage of the teletype machines; the English farmer is much too conservative. It is very difficult to persuade him to take a party-line telephone; and when some time ago the Post Office telephone authorities distributed weather forecasts from their rural exchanges, it was found that so few people wanted them that they have been practically discontinued. Another important point is that these machines must be so constructed as to require no adjustment at the subscriber's office. Although I do not think that the sounder will become obsolete, its use will continue to diminish and the tendency which there has been of late years to make the telegraphist either a typist or a mechanic will continue at an accelerated rate. The type printer is bound to supersede the sounder for the greater part. It is rather surprising—as showing the conservatism of the ordinary English user—to find how little the facilities which the telephone administration does give in other directions are made use of. For instance, very few people take advantage of the system whereby a telegram may be addressed to a person's telephone number, thus enabling the message to be telephoned from the main telegraph office and saving the time occupied in delivery.

Mr. A. E. Thompson: In view of the subtlety of the distinction which the author has drawn between the telegraph and the telephone, the fact that the ordinary business man with the telephone at his elbow uses it for much traffic that could be handled more economically by the telegraph is not surprising. Undoubtedly the telegraph has suffered by the want of a satisfactory connecting link between the user and the administration. Instead of being regarded as a normal means of communication, it is only used in extreme necessity and it has thus become associated not with the active side of life but rather with catastrophe, sickness and death. Telegraphy has thus itself become enfeebled. In comparing the relative transmission efficiencies of the telegraph and the telephone, the author states that when the word "Paris" is spoken, 365 waves are transmitted, as against 21 waves when the same word is telegraphed. This assumes that only the fundamental frequency is transmitted in the case of the telegraph, whereas the square-shaped signals necessary for machine speeds are built up from a number of harmonics. The importance of these harmonics is clearly illustrated by the "composite" system of superimposing. In this system the telegraph signals have to pass through a filter network having a fairly sharp cut-off at about 80 periods per second. It is not possible, however, to telegraph at this speed, and in practice the maximum speed obtainable is between 20 and 25 periods, which is sufficiently low to permit the third harmonic to pass freely through the filter. A more direct, and more striking, illustration of the admitted economy of the telegraph, from the line standpoint, is afforded by the Western Electric Co.'s "voice frequency" telegraph system. Take, for example, a 4-wire telephone circuit providing one speech channel in each direction. If the telephone is given up, and if the same line plant is then equipped at its terminals with the Western Electric system, from 10 to 12 independent telegraph channels can be obtained. Each of these channels may, in turn, be equipped with multiplex-quadruplex printing telegraph apparatus, giving a total of 40 to 48 message-channels, or a traffic-carrying capacity of approximately 1 200 to 1 400 words per minute. If only two wires are available the traffic-carrying capacity is reduced to 600 or 700 words per minute, but this is still considerably more than the telephone can handle. In the section dealing with teletype exchanges, the author states that the Bell Telephone Co. is starting to sell telegraph typewriter service to business men in Chicago, on similar lines to the Western Union. This may perhaps give the impression that leased wire telegraph service is a new practice in the United States, whereas the Bell Telephone Co. has, of course, been leasing printing telegraph facilities for a number of years past. The only new feature is that the Illinois Bell Telephone Co. of Chicago is now offering the teletype apparatus for use on its lines. With regard to the telegraphy of the future, a matter which requires some consideration if the telegraphs are to be linked up on an extensive scale is the establishment of a standard 5-unit code. At present three or four different arrangements of this code are in use in Europe, but investigation will probably show that the code used by the "teletype," the Murray multiplex, and the American multiplex and start-stop systems, is the most satisfactory from every point of view. When the administrations adopt a common 5-unit code, then with such developments as the simple typewriter-telegraph, the "composite" system, and the "voice frequency" telegraph system, the author's vision of the new telegraphy should soon be realized. As Mr. John Lee, the Controller of the Central Telegraph Office, so aptly states in his book "Telegraph Practice," "The old mystery of the telegraph is breaking down; the public is no longer to be separated from the organism by the fortification of a counter. The telegraph system is no longer to find its bounds and limits in telegraph offices. It will penetrate into industry itself, it will link up all manner of industries with each other and with whatever centralizing bureau shall yet be evolved."

Major F. H. Masters: A previous speaker has stated that the facilities available for telephone subscribers are not made use of, and complained that it was difficult for the Post Office to advertise those facilities. A body known as the Telephone Development Association has recently been formed, and it would appear that it should be part of their duty to advertise existing facilities. I should like to suggest to the author that some of the advantages which he puts forward for the teletype system could be obtained rather more simply by using the telephone in connection with the telegraph.

Mr. W. J. Thorrowgood: A point of view which does not appear to have entered into the author's calculations concerns the user of this apparatus. It has been said that the user of a telephone does not always know how to manipulate a receiver after he has used it. If he is to use the teletype machine to any extent, I venture to say that the cost to him of learning how to use it will be very considerable. A man operating a typewriter at 40 words a minute must give his whole attention to the work; whereas if he speaks over the telephone he is thinking of what he is saying, and he conveys a good deal by the way in which he says it. The teletype writer to an ordinary user is not so comfortable to use as a telephone, and a telephone lends itself so easily to business men that it seems to me that a teletype has no chance at all—certainly in view of the possible advances that can be made in 25 years, the period mentioned by the author. When calculating the number of words that can be sent by telegraph, or telephone, it must be considered that the unit of telephone communication is not letters, words, or messages, but a conversation, which may consist of several messages, certainly not less than two.

Mr. A. C. Brown: There is one thing which might very easily alter our conception of the whole subject, and that is the "Telephonograph." That, of course, is not a new proposition; it is quite possible now for telephone subscribers to have an instrument which will automatically start when a call is given from the exchange, and which will record the telephone message and deliver it up when it is wanted. I fancy that a considerable use of such apparatus would enable a great many of the difficulties of switching to be avoided, and might possibly considerably affect the number of telegraphs required.

Mr. J. S. Jones: The author appears to base his attack on the existing telegraph service in this country on two paragraphs which appeared in the *Daily News.* The first of these paragraphs, however, has no reference to the British telegraph service and the second is largely incorrect. The alleged system of telephoning express messages from one exchange to another has never existed and the subscriber at Norwood, far from having a new facility in being put through to the Central Telegraph Office, has in fact had that facility for 30 years. I do not think, judging from the evidence at the General Post Office, that the public is dissatisfied with the present telegraph service. The author thinks that there are too many circuits and I take it that he means that the Post Office does not take proper advantage of the devices which exist for superposing and multiplexing. Leaving reserve wires out of account, there are very few telegraph services in this country which require two or more wires, for the reason that multiplex working is in operation on all heavy routes. Presumably the author's view is that more could be done to cut down the number of physical circuits by forming channels by multiplexing, or by the tone-frequency method, and extending them by short-distance physical circuits—for example, by forming a number of such circuits between London and Birmingham and extending them to Nottingham, Manchester, etc. Such a method, however, has the great disadvantage of placing too many eggs in one basket. In any case, expedients of this kind could be applied to very few routes in this country. A system of transmitting centres as advocated by Mr. Newlands was in fact introduced in the British telegraph service nearly three years ago. It had some effect in reducing the number of re-transmissions of telegrams, but it could not reduce the number of re-transmissions per message by 2, as asserted by Mr. Newlands, for the reason that the average number of re-transmissions per message is actually 1·2. The author envisages the telegraph service too much as a business-man's service. It is used by all sorts of people, and the number of persons sending more than, say, three telegrams a day is comparatively small. A very few send large numbers of telegrams and the system of direct telegraphing proposed by the author would be quite unsuitable for them. The author proposes the establishment of a telegraph system practically on the same lines as the telephone service, but such a service would involve the provision of three or four times as many telegraph channels as exist at present. There is unquestionably a field for teletype exchanges, but it is highly improbable that the possibilities of development are as extensive as the author suggests.

Mr. G. F. Findley (*communicated*): It would appear that in order to obtain a true vision a forecast of the telephone development must be placed alongside the forecast of the new telegraphy. In view of recent achievements it is not necessary to consider the telephone development 25 years hence. I think that the development of telephony in the next 10 years will make the present system appear very crude. The improvement in the telephone service provided by the "no delay" conditions created within the London "toll" area, between the Liverpool area and the Manchester area, between the Glasgow area and the Edinburgh area, etc., and the advance in transmission efficiency, manufacture, laying and maintenance of telephone cables and, last but not least, the advance made in the telephone repeater, force me to anticipate a telephone development along the following lines:—

(1) It will be possible at moderate charges for calls between all large cities to mature with a maximum delay of 10 minutes and for calls between towns within the vicinities of these large cities to enjoy the same standard of service. In fact, practically the whole of Britain should have a 10-minute service on terminal calls.

(2) The maximum delay on a call from Plymouth to Aberdeen (a through call) should not exceed 20 minutes.

(3) The telephone will become as vital as electric light and power, water, etc.

As the natural way to communicate with one another is to talk, I am unable, in view of my vision of the telephone development, to realize how the author's scheme can live. There will be no necessity to "teletype" when one can "teletalk" without delay and for a moderate charge. Where documentary confirmations are essential—and I am of the opinion that with the advance of telephone education these confirmations will be very few—the post will be sufficiently speedy. The author appears to have overlooked also the ease of correction by telephone as compared with teletype, especially simplex teletype, working. He says that, with the new telegraphy, telegraph instrument rooms will be deserted, as they will become switching centres and the stability of circuit conditions will be established. At present, it would appear that every circuit is worked under different conditions and that any scheme which embodies the word "economy" a sufficient number of times is given prominence and a trial. I think that one of the real planks of economy is efficient standardization and mass production, which will cheapen the article to the consumer. With simple apparatus such as the telephone and a straightforward issue, viz. "The required persons to talk," a delay of 60 seconds is experienced on long-distance calls, after the subscribers' telephonists have answered, before the required persons commence talking. I can see a considerable increase to this delay before "the required persons can type." Therefore in all the circumstances—the main being the development of the telephone—I cannot see the necessity to "teletype" when one can "teletalk" with efficiency and economy.

Mr. T. E. Herbert (*communicated*): The first two parts of the paper may be described as an extension of a paper * read before the Institution of Post Office Electrical Engineers at Manchester on the 3rd March, 1924. In general, the conclusion arrived at in the paper quoted is the same as the author's, viz. that the time has arrived when some form of automatic switching must be adopted. The telegraph ought to be the cheap, speedy and democratic method of conveying messages which cannot suffer the delay of the ordinary post. The cost of the telegraph plant is necessarily much less than that of the corresponding telephone plant required to convey a message over a moderate distance. If the plant or capital charges of telegraphs are compared with trunk-line capital charges, it will be found that the latter are much heavier. The net receipts from telegraphs are higher than for telephone trunk lines, and yet the former consistently register a loss and the latter a profit. The operating costs, including the cost of delivery of messages, are very high. By eliminating the re-transmission of messages, not only is the cost reduced but greater expedition is secured. It is, of course, a matter of opinion as to whether the business community can make use of a quick telegraph service, but it is certain that present-day business could not be conducted without our present means of rapid communication and transport, mechanical and electrical. It therefore seems reasonable to suppose that increased rapidity has a definite monetary value, and it scarcely seems idealistic to suppose that in time greater expedition in business arrangements will become, not a luxury, but a necessity. This greater rapidity will have to be paid for, but if the results are commensurate the extra cost of telegraphing letters as compared with the ordinary post will assume very minor proportions. The telephone trunk conversation is regarded as essential for personal communications and personal discussions of urgency, and from the enormous use made of trunk lines it is clear that this aid to business is fully appreciated. The interruptions by telephone-calls on relatively minor matters are, however, sometimes serious and would be avoided by the use of a telegram—the caller has not to obtain a telephone connection, nor is the called person interrupted in his occupation of the moment. The telegram is received and dealt with in the called person's office, and the consultation which may be necessary for the reply is effected in the least possible time, since all the data are available when the matter is to be decided. All this, however, postulates a service which is cheap and extremely rapid. Close and careful investigation is called for, and from the large number of papers on the subject of telegraphs now appearing in various technical publications, and from discussions by telegraph and telephone societies, I think it is certain that the problems can and will be solved—to this end the author has contributed a most valuable piece of constructive criticism. On page 247 he states that it is hopelessly idealistic to suppose that the telegraphs have value for short distances. It is by no means certain that the value of the written record and the avoidance of interruption to, and by, important executives has no recognized value. In the event of the main telephone exchange in a town or city being destroyed by fire, the telegraphs would serve to mitigate the disaster since there would be no difficulty whatever in providing a relatively large traffic-carrying system at short notice. The restoration of the exchange would necessarily occupy weeks or months, according to the size and nature of this damage. The "engaged" difficulty referred to on page 259 could be met in yet another way. The message might be received on a receiving perforator allied with a transmitter which would seize a waiting point for the line required and, when this was free, proceed to transmit the message. The point to be appreciated is that this machinery standing idle waiting to re-transmit the message saves human labour, and it is the cost of such labour which necessarily keeps up the cost of telegrams. I am disposed to think that special circuits for telegraphs, rather than the joint use of local subscribers' lines save for very small users, is the most probable development. The failure of the London intercommunication switch is not a valid argument against the suggestions now made. It depended on manual switching and on the skill of morse operators at small offices. Also, it seems possible that the area served by each office for delivering messages was too small for economical operation. The first step (p. 264) should, I think, be in the direction of providing an automatic switching system such that no manual re-transmission of messages should take place between telegraph offices. In conclusion, I am by no means in agreement with the author's suggestion that telegraph clerks will disappear. It will be precisely as with automatic telephone exchanges where a large number of women are always necessary for special switching, accounts work, and many other duties. So with telegraphs, a large staff will always be required and if the volume of the work increases under the new conditions I think it more than probable that the functions of the staff may be changed but that great displacement will not occur.

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* T. E. Herbert: "The Problem of the Telegraphs," *Telegraph and Telephone Journal*, 1924, vol. 10, p. 126.

Mr. Donald Murray (*in reply*): I am glad the Institution has given me so much liberty in the preparation of this paper, because I might have been asked, quite fairly, to make it more technical in tone and substance. In view, however, of the importance of attracting public attention to the idea of teletype exchanges, it would have been unfortunate if any restriction had been imposed on the popular journalistic method of presentation that I have adopted. Technical men would also have been justified in complaining of the length of the paper; but it has been well said by Sir Oliver Lodge that "effective exposition cannot be done crisply and compactly." For these and other reasons I expected a good deal of adverse criticism, and I have therefore been agreeably surprised at the very friendly tone of the discussion and the considerable degree of approval given to the scheme advocated in the paper.

It is most encouraging to hear from Colonel Purves that the British Post Office is keenly interested in the proposals which I have put forward, and that steps are being taken to investigate the scheme with a view to giving it a practical trial. I am also glad to hear from the Engineer-in-Chief of the British Post Office that on the engineering side the scheme presents no serious difficulties, and that it is essentially an economic problem. That is a point upon which I have laid emphasis in the paper, and I am glad to have it confirmed by so high an authority. Colonel Purves makes a good point about the relative efficiencies of the receiving appliances in the case of the telephone and telegraph, in the one case the enormously sensitive and intelligent human ear, and in the other case inanimate and comparatively insensitive telegraph apparatus. My reply is that vacuum tubes now far exceed in sensitiveness the human ear, and that there is no reason why all the telephone methods (including vacuum tubes) should not be applied to telegraphy. It is a physical impossibility to avoid the consequences of the facts displayed in Fig. 1. In any case the margin of about 100 to 1 in favour of the telegraph and against the telephone is so great that heavy discounts can be allowed in respect to points such as that to which Colonel Purves has referred.

Another point made by Colonel Purves is that he is not impressed with the suitability of the printing-telegraph for sending and receiving service switching instructions, and he is evidently not prepared to shut out the possibility of combining the teletype and telephone, switching from the one to the other at will. I am glad to hear that, and two French inventions appear to make it practicable to work start-stop printers through ordinary telephone exchanges in conjunction with telephones.

The criticisms by Mr. Newlands are also very helpful. I agree with him that the present cost of start-stop printers is far too high. It is a new industry, however, and the preliminary expenses have been heavy. When the industry begins to pay its way, prices will come down. That has been the experience in all industries. It is very encouraging to have the opinion expressed by Mr. Newlands that when prices come down, as the result of bulk manufacture of start-stop printers in this country these machines will make very rapid progress indeed. Mr. Newlands refers to what I have called "bottle-necks"—points where telegraph messages accumulate and have to wait their turn. That, of course, would prevent direct communication; but the telegraph service at present is full of bottle-necks, with consequential delays and waste of labour in writing down telegrams, and it is one of the attractions of the printing-telegraph exchange idea that it will greatly reduce the number of bottle-necks, and possibly in time abolish them altogether.

I admit that to work over 5 000 miles with the teletype is rather idealistic under present conditions; but it is not impossible, because the Western Union Company is working six multiplex installations on six telegraph wires right across the American continent, a distance of about 3 300 miles. Each of these wires is carrying 100 words a minute simultaneously in each direction. Under these circumstances, to work the teletype at 40 words a minute over 5 000 miles presents no technical difficulty at all. In fact, on wires 3 000 miles long it will be easy to have two teletype channels simultaneously in each direction on one wire, a result eight times cheaper than the telephone, even if the telephone could work over such a distance with no more costly technical appliances than the telegraph, a thing that it certainly cannot do.

The points raised by Mr. Shaughnessy are also good. Certainly the price of start-stop printers will have to come down very much before there can be any great extension of their use; but the present high prices are the main factor that will render it possible by and by to get the price down to a point much below the present rate. Capital must be accumulated to make cheap manufacture possible, and the manufacture of such machines must first reach the remunerative stage. That condition has not yet been fulfilled.

Mr. Kingsbury's remarks are specially interesting because they express the telephone point of view. His analogy with passenger and goods traffic on railways is illuminating and is rather adverse to the teletype exchange scheme, though he agrees that it is a question of cost and convenience. It is very instructive to hear that the telegraph exchange plan was patented as far back as 1851, because it is remarkable to note how many good ideas have been published and forgotten long ago, the time not having been ripe for them. In my paper I have taken the same line as Mr. Kingsbury in favouring separate teletype exchanges; but it is a point about which there appears to be considerable difference of opinion, especially in view of the two French inventions to which I have referred and in view of the wonderful capabilities of vacuum valves.

One point mentioned by Mr. Johnson is the difficulty about switching over from short to long lines. This certainly makes it difficult to apply the duplex balance in every instance; but in the case of simplex working there is no more difficulty in switching the teletype from short to long lines than in the case of the morse key and sounder. I am glad that Mr. Johnson draws attention to the waste of labour, inevitable under the present system, of writing down telegrams and rewriting them several times. That is one of the strong points in favour of the teletype exchange. As for the cost of labour at switching centres, referred to by Mr. Johnson, it seems to be not unlikely that automatic telephone exchange machinery will take care of this difficulty.

An important point was raised by Mr. Thompson about my comparison of telephone and telegraph signalling in Fig. 1. The harmonics giving practically square-shaped telegraph waves certainly would reduce the ratio of 365 : 21; but telegraphy with the fundamental frequency only and without any serious admixture of upper harmonics is possible, and has indeed been advocated by Rowland, Squier and others. In any case the number of different harmonics in line A, Fig. 1, must of necessity be very large, and line D makes some approach to one fundamental frequency. The unavoidable difficulty, so far as telegraphy is concerned, appears to me to be not harmonics but the changes of phase in the waves, which have to be made in order to transmit signals, because a pure sine-wave alternating current cannot transmit intelligence. For instance, in line D (Fig. 1) a half wave has been suppressed at P, thus throwing the succeeding waves completely out of step. In the next letter, A, a half wave has been reversed from negative to positive. These changes of phase cannot be good for telegraphy when filter methods are employed; but telegraphy is impossible without either such changes of phase or changes in amplitude. Experience has shown that the latter are inadmissible, so we are left with changes of phase as the only practicable method of telegraphy. Just what effect this has on the comparison in Fig. 1 I do not know; but the facts mentioned by Mr. Thompson indicate that it may be considerable. The figures given by him, in regard to the number of channels into which a telegraph wire can be split up by the Western Electric Co.'s methods, are astonishing and confirm the arguments in the paper. Mr. Thompson raises another important point, namely, a universal 5-unit telegraph code. That is a matter which will have to receive the attention of the telegraph administrations in the near future.

Major Masters, in suggesting that the telephone-telegraph combination would give some of the advantages which I have put forward for the teletype exchange scheme in a more simple manner, appears to me to have overlooked the economic consequences of Fig. 1 and the saving in labour in telegraph offices by the teletype combined with teletype exchanges. That is impossible of achievement by the telephone-telegraph combination.

Mr. Thorrowgood raises the point about the difficulty of using the teletype, compared with the telephone. The same argument applies to the typewriter. Business men do not use typewriters: they dictate their letters and telegrams now, and the only change will be that they will dictate more telegrams and fewer letters, and their typists will be as expert on the keyboards of the teletypes as they are now on the same keyboards of typewriters.

Mr. Brown's suggestion about combining the phonograph with the telephone is unfortunately not practicable, and it also disregards the economic consequences of Fig. 1.

Mr. Stuart Jones pointed out that the first newspaper paragraph quoted by me does not apply to the British telegraph system. In reply I may point out that my paper deals with telegraphy throughout the world, and not only with the British and one or two other telegraph services which are relatively good. I am sorry to say Mr. Stuart Jones is right in asserting that the British public (and, I may add, also the American) are not dissatisfied with the telegraph service. My point is that they ought to be, and my paper has been written to inspire the public with a little divine discontent on the subject. I want to galvanize the public into demanding something far better not only for themselves but also for the telegraph administrations.

Mr. Stuart Jones makes a good point about the danger of putting all one's eggs into one basket; but the risk depends on the kind of basket. Underground circuits are wonderfully reliable and weatherproof. As I have pointed out in reply to another speaker, it is not business men but their typists who will do the telegraphing.

Mr. Findley, like several other speakers, has concentrated his attention too much on England. I wrote for the world and not only for Great Britain; I took a cosmopolitan view. Several speakers expressed doubt about the farmer ever using the teletype. Mr. Johnson, for instance, said that English farmers are too conservative to use the teletype; but if he will refer again to pages 254 and 255, he will find that I expressly exempted the British farmer and mentioned farmers in other parts of the world, particularly in America, as probable very large users of the teletype. Again, a careful study of the economic consequences of Fig. 1 will show Mr. Findley the need for teletyping, in spite of our being able to teletalk with efficiency and economy. Distances are short in Great Britain, and there is no reason why Mr. Findley's visions of a greatly improved telephone service in this country should not be realized; but the great new countries of the world, the United States, Canada, South Africa, Australia, Russia, Siberia and South America have very long distances, which make the economic consequences of Fig. 1 very important indeed.

I welcome the support given to my forecast of telegraph development by Mr. Herbert, whose paper was most suggestive. It made no mention, however, of the idea of getting every business man to do his own telegraphing, just as he does his telephoning, direct to his correspondents through teletype exchanges. That is the essence of my paper. Mr. Herbert stresses the fact that it is the cost of labour that makes telegrams costly. Obviously the remedy is to abolish the costly labourers—the middlemen workers—and transmit and receive telegrams direct. I note with interest that Mr. Herbert, like many other Post Office engineers, is a supporter of automatic switching for the proposed teletype exchanges.

In conclusion, I should like to draw attention to a probable method of using the teletype efficiently through teletype exchanges, namely, storing up messages and sending them through by teletype on one call. Business men already do this in the case of long-distance telephone calls, when these are a daily occurrence. They note down beforehand points for discussion when the telephone call is put through, and it seems likely that telegrams to be sent by the teletype through exchanges will be typed ready to be sent through on one call, which may last for 10 or 12 minutes. In that time two expert typists would easily exchange 500 words between two offices 1 000 miles apart, and on a line equipped with the duplex balance the number of words could be raised to 1 000. This method of working would greatly increase the efficiency of the teletype exchange by increasing the ratio of profitable working time compared with the time spent in getting connected.

THE PREDETERMINATION OF THE PERFORMANCE OF INDUCTION MOTORS.*

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Summary.

The accuracy with which the performance of induction motors can be forecast in actual practice has not yet reached that attained in connection with other types of machines. An indication of this lies in the recognized tolerances on guarantees, especially those on power factor. The inaccuracies do not arise from ignorance of the conditions on the designer's part but rather from lack of time to take into account all the factors.

This paper is intended to describe a quick yet accurate means of predetermining the performance of induction motors. A group of accurate formulæ is developed on the basis outlined by Steinmetz and is given alongside the corresponding approximate formulæ which have hitherto been much used on account of their simplicity. Curves are then drawn showing the difference between the results given by the two groups of formulæ, the ratios being expressed as correction factors. It is thus possible to obtain results approaching the accuracy of the more involved systems of calculation, by using the simplest formulæ and applying the appropriate correction.

Finally, two examples are given indicating the accuracy obtained by the use of the curves.

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(1) Introduction.

It has often been pointed out that by using the graphic method of "inversion," or the exact mathematical method outlined by Steinmetz, the performance of induction motors can be predetermined with greater accuracy than by using more common methods. The labour involved, however, in using either system has so far prevented their adoption in the engineering and design departments of most firms.

The circle diagram in its simplest form is based on a constant value of magnetizing current from standstill to synchronism and also takes no account of the change in phase angle between the mutually induced E.M.F. in the primary winding and the applied voltage. The calculation of the performance of a motor on a basis of this simple circle diagram can be easily and rapidly carried out and has already been reduced to the application of a number of well-known formulæ.

The method here suggested for predetermining the performance of an induction motor is an endeavour to obtain the accuracy of the more involved systems with the rapidity of application of the simplest.

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